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THESIS

INNOVATIONS IN AIR INSERTION (INVOLVING PARACHUTES)

by

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March 2008

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Numerous innovations in parachuting and related technologies have developed in recent years that had their genesis in the military application of parachutes, which started early in the twentieth century. Although many of these new concepts have not been applied to military operations, they may have much to offer in the future. The innovations covered in this study involve concepts that could revolutionize the use of parachutes in warfare, and focus more on methods than materials. However, some of these related technologies will also be examined.

The five systems covered are: 1) wing suit 2) rigid wing 3) High Glide Ratio (HGR) parachute 4) fixed-object parachuting (commonly known as BASE) and 5) tandem systems. These innovations provide many advantages and improvements to existing systems such as: greater offset for insertion for HAHO and HALO; a capability to conduct infiltration and exfiltration with the same compact equipment; greater capacity for inserting personnel and equipment; and the capacity for expanded use of the parachute in a constrained environment.

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INNOVATIONS IN AIR INSERTION (INVOLVING PARACHUTES)

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requirements for the degree of

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ACRONYMS, ABBREVIATIONS AND SYMBOLS

AAD	Automatic Activation Device
AATV	Airborne All Terrain Vehicle
ARVN	Army of the Republic of Vietnam
ATR	Airborne Trailer
BASE	Building Antenna Span Earth
BMI	Bird Man Instructor
CCC	Command and Control Central
CPS	Complete Parachute Solutions
DARPA	Defense Advanced Research Projects Agency
DM	Decision-Maker
DOD	Department of Defense
DZ	Drop Zone
FJC	First Jump Courses
HAHO	High Altitude High Opening
HALO	High Altitude Low Opening
HUD	Heads up Display
LZ	Landing Zone
MACV/SOG	Military Assistance Command Vietnam/ Studies and Observation Group
MIA	Missing in Action
MFF	Military Free Fall
MTTB	Military Tandem Tethered Bundle
MWD	Military Working Dog

NCO	Non-Commissioned Officer
OPSEC	Operational Security
PARIS	PARachute Insertion System
PC	Pilot Chute
PCA	Pilot Chute Assist
PIA	Parachute Industry Association
RSL	Reserve Static Line
SOF	Special Operations Forces
SPELCO	Special Parachute and Equipment Logistics Consortium
TV	Terminal Velocity
USPA	United States Parachute Association
USHPA	United States Hang gliding and Paragliding Association
USSOCOM	United States Special Operations Command
ZP	Zero Porosity

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I. INTRODUCTION

> Science has not yet mastered prophecy. We predict too much for the next year and yet far too little for the next ten.
>
> — Neil Armstrong, speech, Joint Session of Congress, 16 September 1969[1]

A. PURPOSE AND SCOPE

The purpose of this thesis is to provide an overview of some recent innovations in the field of parachuting. It will attempt to determine whether there are any sound, practical reasons for further developing any or all of these innovations in air insertion: the wing suit, the rigid wing, the High Glide Ratio (HGR) parachute, fixed-object parachuting, and tandem parachuting.

The thesis will consider whether the application of these innovations can provide military decision-makers with more options in the future for deploying Special Operations Forces (SOF). It focuses on SOF because their level of expertise and specialized training makes them especially capable of applying such new methodologies and techniques. What is more, all the innovations covered build on existing equipment and concepts currently in use by SOF. Therefore, they could conceivably be used by any military or paramilitary force, so further attention to their development, possible adaptation, and adoption is merited.

[1] Neil Armstrong, "Armstrong Quotation," thinkexist.com, http://thinkexist.com/quotation/science-has-not-yet-mastered-prophecy-we-predict/363508.html (accessed July 30, 2007).

There are many technologies that might be applicable within the air insertion and extraction field; for example, certain aircraft and systems associated with aircraft. This thesis will discuss only technologies that involve parachute systems that could be used to stealthily insert and extract military personnel and that can also conceivably be recovered by the operators, so as to leave nothing behind for the enemy.

Conventional airborne insertion (low-level mass airdrops) is a mature technology and method and thus not within the scope of this thesis, which focuses on new and developing parachuting technologies and methods that specifically benefit covert and/or clandestine forces.

In 1903, the Wright brothers became the first pilots to achieve a sustained flight in a heavier-than-air aircraft. At the time, few imagined what this meant for future warfare. Less than a decade later, however, militaries applied the technology in combat. The world's first, limited military use of heavier-than-air aircraft occurred during World War I, but it was not until 25 years later that the full potential of this technology for a fighting force became evident. It was only when the political and military decision-makers began to view airplanes as war-fighting tools that the desire and need for them began to drive the technology. It was this historical motivational shift that created over time a revolution in the military's use of aircraft, resulting in jet aircraft, bombers capable of carrying large payloads, and aircraft capable of taking off and landing almost anywhere. In sum, what drove the flight industry was the

compelling need to develop and innovate above and beyond anything normally conceived of as possible.

Despite that historical progress, the development of parachute technology for war fighters did not proceed in a similar fashion toward fulfilling its original promise and potential. The major difference between the progressive development of military aircraft technology over the advancement of military parachute systems was the absence of a similar historic shift in motivation pertaining to parachutes. Parachute system development is still motivated by the technology that is available, not by a driving need for more innovative systems.

We posit that a comparable motivation shift may never occur. After all, the military application of parachute systems is more limited than that of aircraft. In this case, the military is doing little or nothing to drive parachute technology or develop new applications. Instead, the civilian sector is developing new applications and driving the technology to better match those applications. Thus the goal of this thesis is to explore existing and emerging parachute systems and application development for possible military use. To do so, the thesis is divided into three chapters.

Chapter I looks at:

- The earliest military uses of parachutes and the ways that various nations approached their airborne programs.
- The current U.S. military's parachute insertion capability.
- The effect future conflicts might have on the use of parachutes and the development of air insertion operations and technologies.

Chapter II examines:

- Five parachute innovations.
- Potential use by SOF in future operations.

Chapter III presents conclusions and recommendations based on the thesis research, including:

- The first use of HALO discussed and recommendations made concerning the adoption of these advanced capabilities to HALO and HAHO.
- McRaven's six principles of special operations are explored and related to implementing the various innovations.

B. BACKGROUND

1. A Brief History of the Early Uses of Parachutes for Military Air Insertion

Initially, the U.S. military used parachutes primarily as lifesaving devices for the crews of stricken aircraft. The use of parachutes for emergency egress from tethered spotting balloons proved successful during World War I. More than 800 lives were saved. The pilots of fixed-wing aircraft, however, were slow to accept and adopt similar equipment and methodology. Their resistance to these innovative lifesaving measures stemmed apparently from a belief that, as some said, "they might reflect negatively on their faith in the craft."[2] Interestingly, the Germans were not affected by such factors. As early as the spring of 1918, crews were seen parachuting from disabled German fighter planes.[3] Not until after Lieutenant Frederick

[2] Robert O'Connell, "Golden Parachute: Saving Combat Crews," *MHQ: The Quarterly Journal of Military History* 10, no. Autumn 1998 (1998), 99.

[3] Robert O'Connell, "Golden Parachute: Saving Combat Crews," *MHQ: The Quarterly Journal of Military History* 10, no. Autumn 1998 (1998), 99.

Niedermeyer was killed in March of 1922 did parachutes become mandatory for all U.S. Army fliers.[4]

The Italians were the first to explore the use of parachutes for ground forces. In 1927, they initiated an airborne program using an existing type of parachute, the “Salvatore.” The “Salvatore” was the Italian version of the American “Guardian Angel” parachute, which was designed to allow aircrews to escape from a damaged aircraft.[5]

The next use that ground forces developed for the parachute was in 1930 when the Soviet Union established an airborne army. By 1931, Soviet aviators had made 600 descents, and in 1932, 2,000 more parachute jumps were made by military personnel. But Soviet interest in parachuting was not just among the military. By 1935, 1,300 parachute clubs had been established in the Soviet Union, and there were 115 parachute centers, where more than 8,000 civilians underwent training. Whereas the Italians had used a static line parachute system, the Soviets took a different approach, using a manually operated ripcord.[6] The Soviets also deviated from the norm by adopting square parachutes, which they chose in the late 1930s and had, by 1940, become the dominant equipment type in regular use. The apparent advantages of square parachutes over the round parachutes of the day were that the square parachutes provided forward movement through the air and did not oscillate and swing

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[4] Robert O'Connell, "Golden Parachute: Saving Combat Crews," *MHQ: The Quarterly Journal of Military History* 10, no. Autumn 1998 (1998), 101.

[5] John S. Weeks, *Airborne Equipment: A History of its Development* (New York: Hippocrene Books, 1976), 12.

[6] John S. Weeks, *Airborne Equipment: A History of its Development* (New York: Hippocrene Books, 1976), 14.

during descent and landing. Thus the Soviet Union, early on, had one of the more progressive airborne programs of any nation.[7]

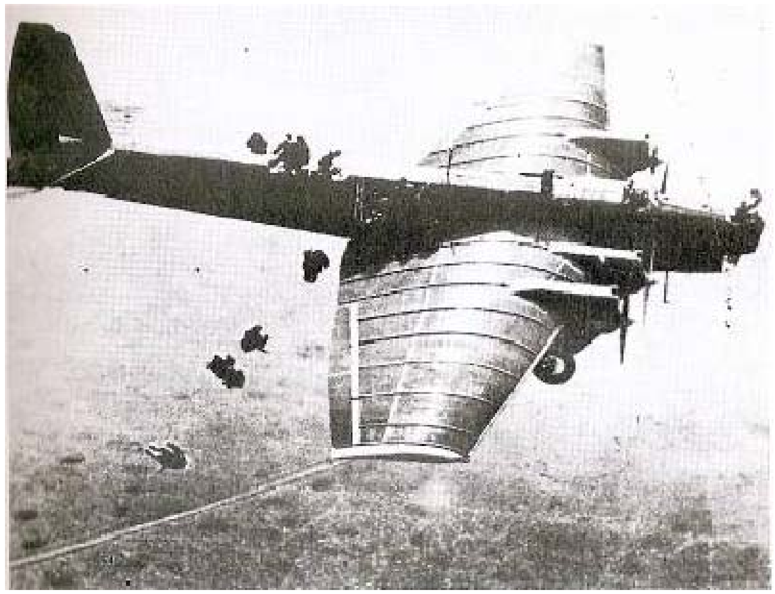

Figure 1. An early Soviet method of exit. From[8]

However, the Germans also had an aggressive and proactive airborne program. The *Fallschirmjager*, the earliest German paratrooper unit, was created in 1938 by Major General Kurt Student under the Luftwaffe. Placing the airborne units under the air force versus under the army was a different approach than that of many other nations both then and in the future.[9] While it is thought that the Germans took Soviet ideas for an airborne force and adapted them for their own use, Germany had a different method

[7] John S. Weeks, *Airborne Equipment: A History of its Development* (New York: Hippocrene Books, 1976), 21.

[8] John S. Weeks, *Airborne Equipment: A History of its Development* (New York: Hippocrene Books, 1976), 13.

[9] John S. Weeks, John H. Batchelor, *The Airborne Soldier* (Poole, Dorset: Blandford Press, 1982), 20.

entirely for their parachutists' deployment. They saw little use militarily for adopting a ripcord and chose instead to use a static line. They also opted for a round parachute.[10] Germany became the first country to use paratroopers in a military operation when, in May of 1941, they dropped 14,000 paratroopers onto the island of Crete.[11]

In 1936, primarily due to the publicity that Soviet parachute troops had received, Great Britain also began an airborne program. However, maintaining that the British started their program this early is actually a bit of a stretch. Indeed, in 1940 Winston Churchill demanded 5,000 parachute troops only to discover that no such force level existed. Years before, Sir Raymond Quilter of the GQ Parachute Company had offered to design a parachute for the British military, but the War Office declined his offer because it did not see a use for parachute troops. Nonetheless, though Great Britain got off to a slow start, it quickly designed a troop-deployable parachute. The "statichute," which would later be known as the X-type parachute, was designed in five days in the summer of 1940.[12]

The United States also began an airborne program in 1940; thus, the 501st Parachute Battalion was already in existence when the Germans invaded Crete by parachute. However, the Americans were way behind in airborne force development. The major shortfall for U.S. airborne troops

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[10] Weeks, *Airborne Equipment: A History of its Development*, 14.

[11] Dan Poynter, *Parachuting: The Skydiver's Handbook*, ed. Para Publishing, 6th ed. (Santa Barbara, CA: Para Publishing, 1992), 94.

[12] Weeks, *Airborne Equipment: A History of its Development*, 26.

during this time was the number of jumpers.[13] Much like the British, America began to develop its parachute-capable forces in reaction to what others were doing. But the U.S. airborne force grew rapidly, and by the end of World War II there were five divisions of well-trained, capable airborne troops. Although the growth of these American forces began later than many, their successes were numerous and important to the achievement of the overall victory of World War II.[14]

Although the inclusion of airborne forces into the U.S. military did not begin until World War II, Americans had already been involved with parachuting for many years. In 1919, the army established a parachute design center at McCook Field in Dayton, Ohio. It was at this center that Leslie Irvin developed a static line parachute system that would be used later. In 1924, a parachute rigging school was started in Lakehurst, New Jersey, at the Naval Air Station.[15] And in 1928 General Billy Mitchell first demonstrated the usefulness of airborne troops by having six military men dropped onto Kelly Field, Texas, where they assembled a machine gun.[16] All of these precursors, the result of America's resolve and ingenuity, helped in developing and implementing a successful airborne force even though this capability was reactively formed.

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[13] Weeks and Batchelor, *The Airborne Soldier*, 24.

[14] Many sources on paratroop's successes in WWII exist but one of the most prolific writings on these troops is Stephen Ambrose's *Band of Brothers*.

[15] Poynter, *Parachuting: The Skydiver's Handbook*, 91.

[16] Poynter, *Parachuting: The Skydiver's Handbook*, 92.

Much like the aircraft innovations that occurred during WWII, parachutes were also developed and improved for military operations. But in later years, while aircraft technology underwent dramatic changes due largely to intense interest and investment by militaries, parachute technology did not. Many years later, parachute technology and operational concepts were essentially the same as they were during WWII - and what incremental changes in technology and innovation did occur were slow and faced much resistance.

2. The Current Capability of Parachutes for Military Air Insertion

While early parachute technology was driven by the military's need for parachutes in warfare, more recent technology has been driven by the civilian sector. The ingenuity of civilians, many of whom had their first exposure to parachuting in the military, resulted in numerous innovations that drastically changed parachute equipment and techniques. The new technologies include computerized Automatic Activation Devices (AADs); the shapes and styles of the main canopies; the materials used in the manufacturing of canopies, such as "zero porosity" (ZP) material; and electronic devices for audible altitude alarms. These are just a few of the technologies developed by civilians that also have obvious applicability to military parachute systems. In some cases, off-the-shelf systems such as the SOV3 Multi Mission System, designed by

Complete Parachute Solutions (CPS), incorporate many of these new technologies already[17] and are slowly being fielded by some units.

Figure 2. MFF Operator tracking across the sky. (Courtesy of CPS) From[18]

The U.S. military's current capability known as Military Free Fall (MFF) consists of High Altitude Low Opening (HALO) and High Altitude High Opening (HAHO) operations. HALO allows forces to stealthily descend directly down from an aircraft at high altitude and to open their parachutes just in time to land safely within a given drop zone (DZ). However, one drawback to HALO is that the jumpers must exit the aircraft either over or close to

[17] "Complete Parachute Solutions (Products)," http://www.cpsworld.com/index.php?which=products (accessed August 13, 2007).

[18] "Complete Parachute Solutions," CPS Inc., http://www.cpsworld.com/ (accessed August 13, 2007).

enemy territory. For this reason, HALO drops are usually made only where enemy air defense cannot threaten insertion aircraft.

HAHO enables forces to leave an aircraft offset from the target, open their parachutes soon after leaving, and navigate quietly (although not as stealthily as HALO) to the target. HAHO drops are made when enemy air defenses pose a threat to the insertion platform. Though HAHO reduces the threat to the insertion platform, it increases the threat and hazards to the operators. The risk of being seen is higher with HAHO than with HALO, and the environmental hazards are also greater. HAHO exposes jumpers to cold temperatures and wind as well as low-oxygen air for extended periods of time, which can lead to hypothermia or hypoxia. Parachute descents through multiple wind levels also increase the chance of off-target landings.

The Department of Defense has designated the U.S. Army as the lead service for military parachute operations. While it is the designated proponent, others also have instructions for using this insertion method and thus we consulted a mix of regulations for our research. The following advantages and disadvantages of MFF are drawn from various publications, including the U.S. Army’s Field Manual 31-19, the U.S. Special Operations Command Air Operations (Parachuting) Manual 350-3, and the Naval Special Warfare Air Operations Manual (COMNAVSPECWARCOMINST 3000.3A).

The advantages of MFF include:

- Precision landing on small drop zones.
- Infiltration of a hostile area when low-level insertion is not practical due to enemy ground fire.
- Infiltration of an area when the use of a low-level insertion is not practical due to terrain limitations such as mountains.
- Simultaneous landing ability at multiple points of an objective while maintaining surprise.
- Increased survivability of insertion aircraft.
- More insertion aircraft type options compared to static line infiltration.
- Low-signature infiltration.

The disadvantages of MFF include:

- Specialized equipment and more intensive training are required for the operators.
- Operator proficiency much greater than that of a typical airborne soldier.
- The need for breathable oxygen on high-altitude jumps. (13,000 feet AGL and above)
- Increased physiological stress and risk of injury during HAHO operations.
- Increased likelihood during HAHO operations of parachute opening shock injury and equipment damage.

3. What type of Air Insertion Capability Will Be Required in the Future?

Parachuting is a necessary military capability. There will always be places where access is limited and air insertion is the best option. For example, when an aircraft

can’t land due to terrain features or restrictions by the host nation; or perhaps the infiltration needs to be concealed and air insertion is the only option. There are a limited number of ways an operator can quietly and stealthily arrive at an objective, and air insertion by parachute remains one of the best options and thus must remain a capability of SOF.

However, even if the U.S. military doesn’t develop new innovations, if the capability of parachute air insertion is to remain a viable SOF option, decision-makers can capitalize on the innovations already developed by civilians. These innovations provide many advantages and improvements to existing systems: a greater offset for insertion using HAHO and HALO; the capability to conduct infiltration and exfiltration using the same compact equipment; a greater capacity for inserting personnel and equipment; and the capacity for expanded use of the parachute in a constrained environment.

Many believe that warfare has changed fundamentally. This theory has merit. At the very least, new and different concepts of warfare will occasionally dominate the battlespace over those previously predominant. John Arquilla, David Ronfeldt, and others argue, for example, that “swarming,” which involves “omni-directional yet well-timed assaults,” will be an important doctrine in future conflicts.[19] Although swarming has occurred in incidents of past fighting, such as in the German U-boat tactics of

[19] John Arquilla, David Ronfeldt, and others, *Swarming and the Future of Conflict*, vii.

WWII,[20] and even as far back as the tactics used by Inter-Asian Steppe horsemen,[21] these tactics and this theory of warfare appear to have become dominant in today’s unconventional battlespace. Arquilla and others attribute this increase of swarming tactics to “the rise of advanced information operations.”[22]

If we are going to engage in “swarming” warfare or whatever other form of warfare the future holds, it seems prudent to stay ahead by using and further developing the air insertion concepts discussed here. The days of massing airborne troops may or may not be over, but the time for precise insertion of multiple operators into denied or semi-permissive environments is already upon us. Airborne insertion comprises only a small portion of a successful swarming plan, but it is an important part. Now that precision munitions are available and predominant, the days of carpet bombing are probably over. Like precision munitions, the innovations discussed here will allow operators to penetrate a target area more precisely and stealthily. Precision clandestine parachuting may be the pinnacle of parachuting in military application.

In his book *SPEC OPS: Case Studies in Special Operations*, William H. McRaven discusses the concept known as “relative superiority,” which he defines as “a condition

[20] John Arquilla, David Ronfeldt, and others, *Swarming and the Future of Conflict*, 17.

[21] Robert L. O’Connell, and John H. Batchelor, *Soul of the Sword : An Illustrated History of Weaponry and Warfare from Prehistory to the Present* (New York, N.Y: Free Press, Distributed by Simon & Schuster, 2002), chapt. 4.

[22] Arquilla, Ronfeldt, and others, *Swarming and the Future of Conflict*, vii.

that exists when an attacking force, generally smaller, gains a decisive advantage over a larger well-defended enemy."[23] In keeping with this concept, McRaven explains, the success of a special operation is directly related to how quickly relative superiority can be attained. As asymmetric warfare continues into the 21st century, relative superiority will become more and more significant. The innovations discussed in Chapter II of this thesis, and the developments that can arise from those technologies, have the potential to provide America with that superiority in future conflicts.

C. OBJECTIVE

> Every new idea (innovation) goes through three phases: ridicule, contemplation, acceptance.
>
> -Old Adage

As it was during WWII, the U.S. is behind the times in implementing many of the new innovations associated with parachuting during military operations. Whether one accepts the doctrine of swarming as the next generation's preferred method of warfare or some other concept of how warfare will be waged in the future, the findings presented in this thesis may well provide the basis for the air insertion of tomorrow.

In a recent article entitled "Showstoppers," Richard Schultz spells out nine reasons why SOF were not used prior to September 11, 2001. He quotes General Pete Schoomaker as saying, "But Special Operations was never given the

[23] William H. McRaven, *Spec Ops: Case Studies in Special Operations Warfare: Theory and Practice* (Novato, CA: Presidio, 1995), 4.

mission. It was very, very frustrating. It was like having a brand-new Ferrari in the garage, and nobody wants to race it because you might dent the fender."[24] What this thesis intends to do is explain the new tires that have been developed since the purchase of that garaged Ferrari.

However, the thesis does not attempt to prove that one type of warfare is better than another but to shed light on promising technologies and innovations so that decision-makers can use as reference points when considering them. Our goal is to examine those systems and establish grounds for their eventual acceptance, even though their promise may not be realized immediately. After all, current USSOCOM commander Admiral Eric Olson pointed out recently in a *Tip of the Spear* interview that one of his main priorities is to “sustain and modernize Special Operations Forces… We need to upgrade SOF mobility so we can reach the battlefield faster, and we must equip the SOF operator with the best equipment available.”[25]

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[24] Richard H. Shultz Jr, "Showstoppers," *The Weekly Standard* 9, no. 19 (January 26, 2004), 25, (accessed September 15, 2007).

[25] Mike Bottoms, "Adm. Olson Explains Vision, Priorities," *Tip of the Spear* (August 2007), 24.

II. DESCRIPTION OF INNOVATIONS

A. WING SUITS

1. Early History

The wing suit, which is also known as a “bird man” suit or “bat wing,” is a centuries-old concept. In the 11th century A.D., Eilmer of Malmesbury, later known as the “Flying Monk,” leapt from a monastery tower with a winged apparatus and flew more than 200 meters before falling to earth and breaking both of his legs.[26] Even farther back than the “flying monk” was the Greek myth of Daedalus and Icarus. Although this story about a father and son who escaped imprisonment by flying away on wings of feathers and wax is simply a myth, it is evidence that the idea of flying this way is almost as old as man. Man has apparently wanted to fly like a bird since he first saw one soar through the air.

In the 1930s, barnstormers toured America trying many things to draw a crowd. During these days there lived a daredevil named Clem Sohn, who later became known as the “batman.” In 1935, Sohn designed, built, and successfully flew a wing suit that resembled a bat’s wing. In February 1935, launching in his new outfit from an airplane at 12,000 feet, the first bird man made several loops and flew as if he had the wings of a bird. At 2,000 feet, Sohn folded his wings back and deployed his parachute, then landed safely. Sohn had successfully slowed his descent

[26] Michael Abrams, "Step 1: Fire Jet Boots. Step 2: Jump," *Popular Mechanics* 183, no. 6 (June 2006), 48, http://libproxy.nps.navy.mil/login?url=http://proquest.umi.com.libproxy.nps.navy.mil/pqdweb?did=1049496921&Fmt=7&clientId=11969&RQT=309&VName=PQD (accessed June 3, 2007).

rate to an estimated 60 mph from the usual 120+ mph, extending his time in the air to 75 seconds. Sohn took his winged flight across the United States from Missouri to Nebraska.[27] Soon, numerous “bat-wing” jumpers began to experiment with wing suits, although very few were successful and most died during their flights. Many of the suits of this time looked different but were constructed similarly, using a single layered wing with rigid frames covered with cloth. These wing suits were flyable but hardly perfected in their design.

Figure 3. 1936 Clem Sohn and his wingsuit. From[28]

2. Recent History

The modern wing suit was first designed and flown by Patrick de Gayardon in the mid 1990s. De Gayardon was a

[27] Michael Abrams, *Birdmen, Batmen, and Skyflyers* (United States: Crown Publishing Group, 2006), 46.

[28] Leo Valentin, *Bird Man*, 1st ed. (London: Hutchinson, 1955), 33 (accessed April 7, 2007).

well-known stunt jumper and skysurfer[29] who had received his initial parachute training in the French Army. Like many before him, de Gayardon was intrigued by the thought of flying like a bird. The design process[30] for de Gayardon brought him to a new concept of design where the wing was not mono-surface like earlier wing suits but multi-layered with cells much like the ram air parachute. This new suit used technologically newer low porosity fabric and its wings extended from the waist up to the wrists and between the legs from the crotch to the ankles. De Gayardon perfected flight with this new wing suit through jumping hundreds of times[31], many of which were BASE[32] jumps. One of de Gayardon's most famous wing suit accomplishments was exiting a Pilatus Porter, flying alongside it, and then flying back into it.[33] Although de Gayardon was killed on a 1998 wing suit jump, the cause was not wing suit related but rather the result of an easily preventable rigging

[29] Sky surfing is the sport of performing stunts and maneuvers during freefall on a "sky board" which looks similar to a snowboard.

[30] Although Patrick de Gayardon designed and followed through with building the suit, the idea of a multi-layered semi-rigid wings for the suit is said to have come from John Leblanc, the vice president of Performance Designs.

[31] Michael Abrams, "The Birdman of DeLand," *Forbes FYI* FYI, no. 2 (May 26, 2003), 054, http://libproxy.nps.navy.mil/login?url=http://proquest.umi.com.libproxy.nps.navy.mil/pqdweb?did=336029391&Fmt=7&clientId=11969&RQT=309&VName=PQD(accessed June 3, 2007).

[32] BASE is a type of parachuting where the jumper launches from a fixed object. BASE is an acronym for Buildings, Antenna, Span, and Earth.

[33] Abrams, *Birdmen, Batmen, and Skyflyers*, 217.

mistake.[34] This new suit would go on to become the prototype for many flying suits to come.

3. Design of the Modern Wing Suit

The modern wing suit, as designed by Patrick de Gayardon and John Leblanc, flies because of the same characteristics that allow airplanes and birds to fly. The wing suit is essentially a wing, much like a ram air parachute or an aircraft wing. These characteristics are based on numerous principles such as air speed, lift, drag, angle of attack, and glide ratio.

Figure 4. Patrick de Gayardon flying his wingsuit from one edge of the Grand Canyon to the other. From[35]

[34] Adrian Nicholas, "People in the Sport: Patrick De Gayardon," People in the Sport, http://www.bpa.org.uk/skydive/pages/people/gayardon.htm (accessed January 19, 2007).

[35] Nicholas, "People in the Sport: Patrick De Gayardon."

Through the use of gravity, a wing suit jumper develops air speed. This air speed creates airflow across the wing. When the air on the top of the wing suit flows faster than the airflow on the bottom of the flyer, lift is produced. As the air speeds up, the lower the pressure on the upper surface becomes. So the faster moving air on the top surface creates less pressure than the slower moving air below. This difference of pressure on the top and bottom of the wing creates the lifting force on the wing.[36] The orientation of the wing is called attitude and involves three axes known as longitudinal, lateral, and vertical. The rotation along each of these axes is known as roll, pitch, and yaw respectively. The angle of attack involves the pitch angle into the relative wind. As the angle along the lateral axis relative to the wind (angle of attack) increases so does lift and drag. With the increase in lift comes a lengthened time aloft but with the increase in drag comes less horizontal distance being covered. As the angle of attack decreases, the lift and drag also decrease resulting in an increased descent rate but more horizontal distance covered.[37] The glide ratio is computed by the distance the object moves forward in relation to the vertical descent.[38] The glide ratio is affected by the factors mentioned above but is also influenced by such factors as weight of the flying object and the wind.

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[36] *Freefall Extreme,* DVD, directed by Mike Slee (Thousand Oaks, California: Goldhil DVD, 2001) (accessed January 20, 2007).

[37] At some increased AOA (Angle of Attack) the wing suit will reach its stall point and also as the AOA reaches zero the suit will no longer fly.

[38] Scott A. Campos, *Skyflying: Wing Suits in Motion* (Fayetteville, North Carolina: SkyMonkey Publishing, LLC, 2005), 18.

4. Capabilities and Potential of the Wing Suit

Glide ratios of 2.5:1 and greater are commonplace in today's wing suits.[39] Wing suits allow jumpers to slow their descent rate from 120+ mph to less than 40 mph and fly horizontally through the sky.[40] In June of 2005 three Spanish wing suit jumpers left a military C130 aircraft 43,000 feet above Morocco and flew across the Straits of Gibraltar and landed 20.5 kilometers away in Spain.[41] In the summer of 2006 Finnish wingsuiter Visa Parviainen launched off a hot air balloon at 7,000 feet with miniature jet engines strapped to his feet. Parviainen flew in level flight for two minutes before opening his parachute and landing.[42] These milestones are significant and could lead to military applications in the future.

5. Any Military Application?

Should Special Operations Forces (SOF) embrace this new technology? As Gerrit Blaauw, one of the principal designers of the early IBM computers, said, "Established technology tends to persist in the face of new technology." Just like any new technology there can be hesitations to accept anything recently developed until the obvious need for it dominates the thoughts of the operators. Although relatively little freefall and parachuting experience is required to make a first flight in a wing suit, much more experience will be required to employ this new technology

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[39] Abrams, *Step 1: Fire Jet Boots. Step 2: Jump*, 48.

[40] Abrams, *The Birdman of DeLand*, 054.

[41] "How to Cross the Gibralter?- the Story," www.bird-man.com, http://www.bird-man.com/index.cgi?n=history&q=Articles (accessed January 22, 2007).

[42] Abrams, *Step 1: Fire Jet Boots. Step 2: Jump*, 48.

tactically. This pool of experience can only be built once the U.S. forces have accepted and adapted this new innovation.

Wing suits potentially offer the best of HALO and HAHO. With a wing suit, an operator or group of operators could exit a plane offset from a target and descend fast and secretly to the target in broad daylight, opening their parachutes in time to land and complete their mission. Wing suits used in conjunction with such gear as a BASE-specific parachute[43] could also be used to extract or evade the enemy by jumping from a fixed object such as a building, bridge, or mountain top. These wing suits combined with a BASE-specific parachute rig would provide the operator with not only insertion surprise but a means to extract with the same equipment.

Can the U.S. military integrate this new technology into its air insertion toolbox? Training programs and wing suit availability are not a problem. Although the U.S. military is not doing any formal training with this new technology, civilians are training with wing suits on a regular basis. An article written in 2003 by wing suit researcher and author Michael Abrams reported that “about 2,000” people had experienced the birdman suits since the company BirdMan Inc. started manufacturing them in 1999.[44] This number has increased substantially since then. Any given weekend one can visit a civilian Drop Zone (DZ) and

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[43] BASE parachutes are engineered slightly different than most freefall parachutes with such considerations as a design which allows the parachute to open at sub-terminal velocity and will be covered in another section.

[44] Abrams, *The Birdman of DeLand*, 54.

see skydivers flying wing suits. Many of these wing suit jumpers are active or former military.

The level of experience needed to learn to fly a wing suit is relatively minimal. The United States Parachute Association (USPA) recommends a skydiver have a minimum of 500 jumps to attempt a flight or 200 jumps and attend “one on one” instruction from an experienced wing suit jumper prior to flying a wing suit.[45] However, this is simply a recommendation by USPA and any skydiver can obtain a wing suit and give it a try. Many wing suit manufacturers such as BirdMan Inc. have their own formal wing suit training programs that could be used as a model. Currently BirdMan Inc. has more than 100 BirdMan Instructors (BMIs) worldwide qualified to teach first flight courses.[46] There are numerous companies such as BirdMan Inc. in Finland, Jii-Wings in South Africa, Phoenix-Fly in Croatia, Fly-Your-Body in France, and Tony Suits in Florida that manufacture wing suits with different flight characteristics and levels of performance. These wing suits are produced for civilians and they meet their market’s demand. If the military was part of the market, these suits could easily be produced with military capabilities and specifications designed into them. The military could also imitate or use the available training and manufacturing structure.

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[45] United States Parachuting Association, "Skydivers Information Manual, Section 6-9 Wing Suit Recommendations," USPA, http://www.uspa.org/publications/SIM/2007SIM/section6.htm#69 (accessed January 22, 2007).

[46] Jussi Holopainen, Some information, 23 January 2007, (accessed January 23, 2007).

6. Limitations and Shortfalls

Specialized equipment and training required will be more involved than traditional HAHO or HALO. While it only takes a couple hundred[47] MFF jumps to be confident and proficient enough to learn to fly a wing suit, the training required to be adept at flying the wing suit would involve as many more jumps. Using a conservative number of jumps per week (25/ week), an operator could become a skilled wing suit flyer in approximately 16 weeks. This timeframe and its associated costs is greater than standard HALO or HAHO training, but it is much less than the two-year, multi-million dollar effort it takes to train a fighter pilot.

While the wing suit provides a means to cover a horizontal distance for offset insertion via HALO, the current wing suit's range is less than that of other means of offset insertion (Traditional HAHO, HAHO with HGR parachute, & HALO jumps with rigid wing[48]). With a glide ratio of 2.5:1, today's wing suit may not provide the offset capability required for offset insertion. Nevertheless, improvements are being made every day by the civilians who are re-designing them to push the envelope of flight.

The design of today's wing suits limit the amount of equipment an operator could carry with them. However, the

[47] Although a couple hundred jumps in the civilian world of parachuting are not a lot, fewer military members have this much experience and more training would be required for the average MFF jumper.

[48] HGR (High Glide Ratio) Parachute and rigid wing will be covered in detail in later sections.

wing suits that are on the market are not designed for carrying equipment. It is possible to design a suit that allows for equipment (weapon, ruck sack, etc.), but the nature of the wing suit will always limit the amount of equipment an operator can carry. This appears to be the biggest limiting factor because the added weight and drag of equipment will always reduce the efficiency of the wing suit, regardless of additional improvements. Thus wing suit insertion will most likely always be limited to offset insertion for lightly equipped operators on short-duration missions.

B. RIGID WINGS

"To infinity… and beyond!"[49] comes to mind while exploring the rigid wing air insertion innovation, not only because of the resemblance to the wing contraption Buzz Lightyear[50] used to fly but also because of the potential this technology promises. Although many different modes of air insertion exist, this innovation appears to have superior potential for offset insertion of special operators. The notion became a concept when humans first tried to fly. During these days, many ideas of how man could fly existed among inventors and visionaries. Nevertheless, the attempts to fly usually ended in failure. A great number of these approaches failed and were never tried again because of the detrimental consequences of their failure. The rigid wing is one of the concepts that failed with dire consequences but survived nevertheless and

[49] John Lasseter, *Toy Story*, Vol. DVD Disney, 1995) (accessed February 28, 2007).

[50] Buzz Lightyear was a character in the children's film Toy Story who was sent to save the universe from the evil Emperor Zurg.

has evolved into a feasible means for human flight. In 2008, the rigid wing is not only an achievable way for man to fly but a method that future SOF may well be able to employ with great advantage- if they choose to adopt it.

1. Early History

One of the first to successfully fly a rigid wing was former French paratrooper Leo Valentin.[51] Valentin started his life of parachuting in the French Air Force and after leaving the service continued to explore free fall and the search for flight in free fall. He was influenced by birdman Clem Sohn and was destined to follow in the footsteps of this visionary. However, Valentin was not content with the flight that the wing suits of the day provided. With the help of pilot and manufacturer Monsieur Colignon, Valentin began to experiment with other ways to achieve flight in freefall. They designed miniature mock-ups of wings that could be strapped to the jumper and they tested these in a wind tunnel. After a few adjustments the two went on to build life-size wings which Valentin would attempt to fly.[52]

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[51] According to Dan Poynter, in his book *Parachuting: The Skydiver's Handbook*, Leo Valentin is credited with having been the first to achieve stable freefall and developed the "spread eagle" position which some refer to as the "Valentin" position.

[52] Leo Valentin, *Bird Man*, 1st ed. (London: Hutchinson, 1955).

Figure 5. Leo Valentin flying his rigid wing. From[53]

These wings were made of wood very much like the wings of an airplane and were attached to the body by a steel cage. The first rigid wings he built and flew (or tried to fly) did not work as planned but Valentin was persistent in his search for “pure flight.” After many months of various problems, he finally succeeded in flying his wings. Over the next two years, Valentin flew these rigid wings in front of thousands of spectators. Then, in May of 1956, at an air show in Liverpool, he plummeted to the ground under malfunctioning main and reserve parachutes.[54] No one knows exactly what went wrong with Leo Valentin’s fatal last flight. As Clive Barker reports in his book, *The Essential Clive Barker: Selected Fictions*, “The favored theory is

[53] Leo Valentin, *Bird Man*, 1st ed. (London: Hutchinson, 1955), 65 (accessed April 7, 2007).

[54] Michael Abrams, *Birdmen, Batmen, and Skyflyers* (United States: Crown Publishing Group, 2006), 130.

that his wings clipped the plane as he jumped. He started to spin, and the damage to his wings prevented his controlling the descent."[55] Thus it may be that the design of the wings had not killed Valentin but rather an accident and the resulting damage to the wings had been the cause.

2. Recent History

Between the 1950s and 1990s, there is little information about rigid wing flight. However, in the 1990s and early 2000s rigid wing flight has found new interest and seems to be developing and reaching new levels of potential. In 2003, Austrian Felix Baumgartner used a rigid wing to fly across the English Channel.[56] Baumgartner jumped from an aircraft at 30,000 feet and flew more than 22 miles, navigating his way to the landing area on a cliff top near Calais, France. The lightweight carbon fiber mono-wing that Baumgartner used had only a six-foot wing span and allowed him to glide at speeds up to 220 mph with a glide ratio of 6:1. Ironically and tempting fate, Baumgartner named this flight Icarus II.[57]

[55] Clive Barker, *The Essential Clive Barker: Selected Fictions* (London: HarperCollins, 1999), 9.

[56] BBC, "Skydiver in Record Channel Flight," BBC News, http://news.bbc.co.uk/1/hi/uk/3112095.stm (accessed February 22, 2007).

[57] Felix Baumgartner, "502," http://www.felixbaumgartner.com/site/index.html (accessed February 21, 2007).

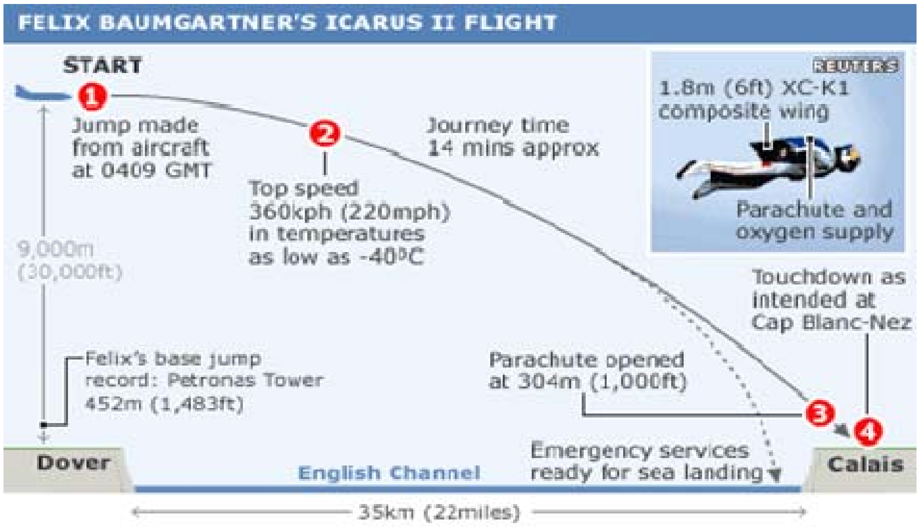

Figure 6. Rigid wing flight across the English Channel. From[58]

Another man who has achieved considerable strides in the design and development of a rigid wing system is aviator and inventor Yves Rossy. This former Swiss Air Force pilot has developed and flown a series of rigid wing systems.[59] The most recent rigid wing incorporated four mini-jet engines that allowed Rossy to sustain level flight as well as climb for more than six minutes. Video footage of his flight shows Rossy maneuvering with other aircraft in and around mountainous terrain.[60] Rossy continues to take his rigid wing invention further and his invention has promise as a prototype for future single man flight. Although he is not designing these for military use, his

[58] BBC, "Skydiver in Record Channel Flight," BBC News, http://news.bbc.co.uk/1/hi/uk/3112095.stm (accessed February 22, 2007).

[59] Jet-man.com, "Jet-Man Performances," http://www.jet-man.com/performance.html (accessed February 22, 2007).

[60] NBC11.com, "Bird? Plane? no, it's Jet Man," NBC News 11, http://www.nbc11.com/news/10574159/detail.html (accessed February 22, 2007).

development and testing could provide much data and ideas for a future military version of the rigid wing system.

Figure 7. Yves Rossy and his rigid wing. From[61]

In 2002, the German company Freesky developed and marketed a rigid wing system for civilian use and named it the Skyray.[62] Since then, a consortium of the German companies Elektroniksystem- und Logistik-GmbH (ESG), Draeger Aerospace, and Freesky have teamed up to develop and market a rigid wing system for military application. This consortium is known as Special Parachute and Equipment and Logistics Consortium (SPELCO).

3. What Kind of "Rigid Wing?"

It is important to explain the type of rigid wing being described in this section. There are different types of rigid wings such as hang gliders that have a "rigid" as

[61] Jet-man.com, "Jet-Man Performances," Jet-man.com, http://www.jet-man.com/performance.html (accessed February 22, 2007).

[62] Freesky, "SKYRAY," Freesky, http://www.freesky.de/SKYRAY.html (accessed February 22, 2007).

opposed to “flexible” wing[63] or a glider that is very much like an airplane with no propulsion.[64] Although these different types of wings may have or previously had military application, they are not the type being discussed. The rigid wing dealt with in this study is used in conjunction with a parachute and fits compactly on the back of an operator. The wing will allow him to traverse great distances and can bring the operative precisely to a target landing area without exposing the transport aircraft to danger or compromising the element of surprise.

This modern rigid wing takes flight because of the same physics principles that allow the airplane or the wing suit to fly. The negative pressure on the top surface of the wing creates lift. This lift enables the wing to transfer the vertical momentum of gravity into horizontal controlled human flight. Controlled flight is the imperative term. For the rigid wing to be useful in military operations it must be able to accurately and safely take the operator to the target Landing Zone (LZ).

4. Capabilities and Potential of the Current Rigid Wing

The rigid wing system developed by SPELCO is named the Gryphon. This mono-wing is made of a composite material known as carbon/aramide and weighs only 30 pounds. With jet propulsion, as in the Gryphon-T, add another ten pounds for

[63] Dennis Pagen, "Rigid Wings - Part I: Spins, Speeds and Safety," USHPA, http://www.ushga.org/article07.asp (accessed February 24, 2007).

[64] SSA, "Soaring Society of America," Soaring Society of America, http://www.ssa.org/ (accessed February 24, 2007).

a total weight of 40 pounds.[65] The Gryphon can carry up to 100 pounds of equipment enclosed in the wing, sufficient space for the tools and equipment of any special operator. A navigation Heads Up Display (HUD) and an active stabilization system for inexperienced pilots has been designed by the consortium to go with this wing. As part of the consortium, the German company Draeger has also developed an oxygen system which fits inside the wing and provides the operator breathable gas for high altitude jumps. ESG claims that the Gryphon-T, with jet propulsion, can transport a person more than 100 kilometers.[66]

[65] SPELCO has inexpensive small turbojet engines normally used for Unmanned Aerial Vehicles (UAV) propulsion which is added in the GRYPHON-T.

[66] SPELCO, "Gryphon," SPELCO, http://www.spelco.eu/library/media/solutions/Gryphon.pdf (accessed February 25, 2007).

Figure 8. Gryphon by SPELCO. From[67]

Skyboard is another rigid wing being designed specifically for military application and seems to possess considerable potential for this type of offset insertion. Steel Works, located in Temuka[68] South Canterbury, New Zealand, has taken on the task of developing and refining a usable rigid wing for military use.

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67 SPELCO, "Gryphon," SPELCO, http://www.spelco.eu/library/media/solutions/Gryphon.pdf (accessed February 25, 2007).

68 An interesting fact is that Steel Works is located in the provincial centre Temuka where Richard Pearse was from. Richard Pearse is the man who some think beat the Wright Brothers heavier-than-air flight by nine months.

Figure 9. First prototype of Skyboard. From[69]

The prototype Skyboard weighs 52 kg but the new version is reported to be half that weight from using newer and lighter materials. All the control surfaces are manually controlled and the system requires no power. The glide ratio which has been attained with the prototype is around 8:1. However, the company claims that a glide ratio of 12:1 will be attained with the newer version.[70] The big difference in this rigid wing and others is the jumper doesn’t land with the wing attached. When the operator deploys his parachute, he leaves the wing and a lanyard is pulled deploying the wing’s own parachute. Steel Works spokesman John Shirtcliff claims that their test jumpers insist the Skyboard is so easy to fly a jumper with 50-100 jumps could master it. The company also claims that this

[69] John Shirtcliff, RE: Skyboard, 2007.

[70] Ibid.

wing can be landed but has not tested that yet. The next modification of the Skyboard is due off the production line towards the end of 2007.

Figure 10. Skyboard by Steelworks in flight. From[71]

5. Any Military Application?

One dilemma with military air insertion is getting soldiers precisely to the target without exposing and/or endangering the delivery aircraft or giving away the element of surprise. Standoff insertion of operators is usually accomplished by HAHO. SOF trains for this capability and, while it is a viable means for offset insertion, the rigid wing improves on this capability. For one thing, the rigid wing is stealthy. Alban Geissler, the inventor of the Skyray, precursor to the Gryphon, claims

[71] John Shirtcliff, RE: Skyboard, 2007.

that the shape and make up of this rigid wing decreases the radar signature to the point where very few if any radar systems could detect it and define it as a threat.[72] Another advantage the rigid wing brings to offset insertions is the limited time that the operator is exposed to extreme cold temperatures. The rigid wing provides both protection and a way for the operator to get to the target much sooner after leaving the insertion aircraft. Another hindrance with HAHO is the effect winds have on the parachutist. The rigid wing minimizes this effect making it much more wind-independent than HAHO.

Figure 11. SPELCO’s Gryphon with description. From[73]

[72] Markus Becker, "FLYING INTO THE FUTURE: It's a Bird. it's a Plane. it's ... Batman?" Speigel Online International, http://www.spiegel.de/international/spiegel/0,1518,428830,00.html (accessed February 21, 2007).

[73] SPELCO, *Gryphon.*

In conclusion, this concept looks to have great potential for SOF. Considering that there are only two companies designing and developing this type of system, one must ponder why more people don’t see the potential for it. Maybe it is simply the fact that the innovation is so new that the perceived reality of the success of this type of system has not taken hold. After all, when aircraft were first being designed there were few aircraft manufacturers and developers. Or maybe the lack of developers is a sign of the times. Although there is a war being waged, the push for innovation is directed more at the urgent threat such as an answer to the Improvised Explosive Device (IED) “problem.” This new innovation would take relatively little money to further develop for use by the US military or simply purchase off-the-shelf from SPELCO or Steel Works.

6. Limitations and Shortfalls

Just like the wing suits, specialized equipment and training required will be much more involved than traditional HAHO or HALO. Although both SPELCO and Steel Works claim their wings are relatively easy to fly, much training will be required before operators could use this innovation tactically. Again, professional level training should not be a showstopper; it is only a factor that should be considered when selecting the innovation for employment. While the system is relatively simple, a high level of confidence and skill must be attained to successfully implement rigid wing operations.

While the rigid wing provides an advanced capability for offset insertion with the advantages of HALO, as opposed to HAHO, the limitation of having the bulky wing to

deal with after landing could be considered an issue. The wings, thus far considered, are not too big to conceivably be buried and recovered at a later date.

While some consideration for equipment has been made with the Gryphon, the Skyboard doesn’t appear to have the necessary capacity for carrying needed gear. Further developed rigid wings could provide a viable means for offset insertion for operators who do not require much equipment. Meanwhile, the limitations and requirements could be addressed by the developers if provided with modest financial incentives.

C. HIGH GLIDE RATIO (HGR) PARACHUTE

A parachute is usually thought to be a means of descent and not ascent. With the introduction of the ram air parachute (an inflatable airfoil with two layers of fabric connected by ribs to form wing-shaped cells) the descent provides more of a directed glide than a fall straight down consistent with the traditional round parachute. In addition, the ram air parachute provides a low impact means of landing by flaring the canopy as the jumper touches down. But, one wonders if the inventor of the ram air parachute, Domina Jalbert, imagined that someday it would become a means of ascent.

Gliders are considered a mode of transportation (albeit without power). These aircraft have a history of use in military operations such as those used in WWII during the allied invasion of Sicily and the airborne landings at Normandy. Gliders provided success because of the quietness and ability to carry numerous troops and equipment into an area providing an element of surprise to

the enemy. However, these were bulky machines that needed to be towed by powered aircraft to soaring height before they could travel. Hang gliders, on the other hand, are usually ground launched but require launch from a steep hill or cliff and, again, the bulkiness of the equipment can be a hindrance. An advantage of most gliders is that they can gain altitude and stay aloft using thermals[74] and waves.[75]

The paraglider can provide the best of both worlds of the ram air parachute and the hang glider. To the casual observer a paraglider appears to be just another ram air parachute but, in fact, it is much more. While the paraglider is similar in design to the ram air parachute, the shape and form of the paraglider provides an advanced capability not possessed by the ram air parachutes. Nevertheless, with those different characteristics come some shortfalls. The High Glide Ratio (HGR) parachute is the innovation which will be described in this section and it combines the potential for use of both the paraglider and the traditional ram air parachute.

1. History

The early history of the paraglider is somewhat murky. Nevertheless, the recent history and developments in the technologies that led to the creation of the modern paraglider indicate that the concept is relatively new. Man has tried numerous ways to get airborne, usually resulting

[74] Thermals are developed by the Earth's surface being warmed and radiating heat thereby warming the air and producing warm, less dense air which rises.

[75] Waves are developed by the airflow of the wind downwind of a hill or mountain range.

in disastrous failure. However, a few pioneers persisted in developing the concept of gliding flight. The paraglider appears to have been conceptualized from different existing concepts such as the kite, the parachute, and the hang glider. The HGR parachute takes these concepts even further.

In the 1940s Dr. Francis Rogallo and his wife Gertrude conducted numerous experiments with kites. These kites led to the development of the triangular hang glider and the “Rogallo wing” which was developed for NASA to be used as an alternative recovery system for the Gemini space capsule.[76] The research these scientists did with kites provided unforeseen multiple order effects in the flying technology of the future.

In 1966 Domina Jalbert patented his “parafoil” which would come to be known as the ram-air parachute.[77] The concept of the ram air parachute remains the same today but it has been refined and further developed to provide the highest performance parachutes ever created. The ram air parachute provides parachutists not only with a steerable parachute with forward penetration but also an airfoil that becomes semi-rigid due to the air inflating the cells of the parachute. Ram air parachutes continue to be improved and their full potential has yet to be achieved.

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[76] Noel Whittall, *Paragliding : The Complete Guide* (New York: Lyons Press, 1995), 9.

[77] Ibid., 10.

Figure 12. 1966 American Domina Jalbert designing the original ram air parachute. From[78]

As mentioned above, the hang glider originates from the invention of the “Rogallo Wing” but did not become popular until the 1970s. The hang glider is a triangle “delta” wing usually made of fabric[79] and kept in the triangle shape by an aluminum or alloy frame. Hang gliders launch from high ground, usually a cliff or steep hill, and can fly many miles.[80] The hang glider provided much to the vision of the paraglider; in that, ascending flight was

[78] Tal Streeter, "Domina Jalbert: The Brother of the Wind," Drachen Foundation Journal, http://www.drachen.org/journals/a10/Domina-Jalbert.pdf (accessed August 20, 2007).

[79] There are some hang gliders which are completely rigid although they are not as common as the fabric winged hang glider.

[80] "USHPA (United States Hang Gliding and Paragliding Association)," http://www.ushga.org/ (accessed August 20, 2007).

achieved with a glider that launched from the ground. The details in how ascending flight is achieved will be covered later.

While paragliding gets its roots from the above discoveries in flight, the first pioneers to use paragliders appeared in the 1970s. These "first paragliders" consisted of climbers in the French Alps who used ram air parachutes to descend the peaks after they had reached their summit.[81] These parachutes had a glide ratio of less than 3:1 but the glide ratios were soon improved by revolutionary non-porous fabric, greater wingspans, and a modified airfoil shape.[82] By the mid to late 1980s the sport of paragliding emerged in Europe and promulgated its further development.

The paragliders that exist today are developed with cutting edge technology allowing them to achieve flight that wouldn't have been imagined 20 years ago. Paragliders manufactured today achieve a glide ratio of 6:1 for recreational types and up to 10:1 for competition paragliders.[83] The world record, for distance traveled using a paraglider, is held by Will Gadd of Canada, who recorded a trip of 263 miles from Zapata, Texas, on June 21, 2002.[84]

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[81] Kurt Kleiner, "From Parachutes to Paragliders," http://www.ushga.org/articles.asp (accessed August 20, 2007).

[82] Ibid.

[83] Wikipedia, "Paragliding," http://en.wikipedia.org/wiki/Paragliding (accessed August 21, 2007).

[84] "History of Hang Gliding and Paragliding," Ouachita Mountains Hang gliding, http://www.ouachitahanggliding.com/History/history.html (accessed August 23, 2007).

Figure 13. Modern paraglider in flight with a flock of birds. From[85]

2. What Type of Parachute?

United States Hang Gliding and Paragliding Association (USHPA) defines a paraglider as “a foot-launched, ram-air, aerofoil canopy, designed to be flown and landed with no other energy requirements than the wind and gravity.”[86] While a paraglider is similar to a ram air parachute there are several major differences. These differences, which mainly stem from the fact that a paraglider is ground launched, include:

- A lighter construction due to the fact that the paraglider doesn’t have to withstand the stress of the opening shock.

[85] "California Paragliding Photos and Movies," http://www.astocker.com/paragliding/ (accessed August/ 23, 2007).

[86] *USHPA (United States Hang Gliding and Paragliding Association).*

- Neither a pilot chute[87] nor slider[88] (or other reefing system) are necessary on a paraglider.
- The number of cells and the wingspan of a paraglider are much greater than that of a typical ram air parachute.
- A paraglider harness doesn't have a container attached for the canopy to be packed and placed in.

Because the modern paraglider is designed to only be ground launched it may not be advantageous as a means for inserting operators. The HGR parachute is the next evolution of the paraglider and the ram air parachute. The HGR is a canopy with the glide ratio of a paraglider that can also be deployed from an aircraft.

3. Capabilities and Potential of the HGR

While the hang glider provides a means for flying great distances using only the wind and air, the size of the system and the take-off and landing requirements limit the military potential for this platform. The paraglider, although it is compact and also provides a means for flying great distance using only wind and air, is also limited by the fact that, as designed, it cannot stand up to the opening shock of an aircraft deployment. The HGR could provide the capabilities of the paraglider and be deployed from an aircraft.

[87] A pilot chute is what is used in a typical free fall parachute to pull the pin and in turn the canopy out of the container.

[88] A slider is what is used on a typical free fall parachute which functions to slow the opening of the canopy.

The HGR parachute would provide not only greater stand-off for HAHO infiltration but also possibly a means for exfiltration using the same equipment, ground launched. Another advantage of the HGR would be the fact that lower drops could reach the range of higher HAHO offset insertion, negating the need for breathable O2 systems. The HGR for military application is not a new or untested concept. An article from March 1995 issue of *International Defense Review* suggested their use would “increase combat effectiveness.”[89]

Figure 14. PARA-FLITE’S High Glide Ratio Parachute. From[90]

[89] Ted Dentay, "Tactical Personal Parachutes: The Next Leap," *Janes International Defense Review* 028, no. 003 (March 1, 1995), 87 (accessed July 31, 2007).

[90] "Para-Flite Inc. PARIS," http://paraflite.com/PARIS.htm (accessed August 21, 2007).

One system which is readily available is the PARachute Insertion System (PARIS) manufactured and marketed by Para-flite Inc. PARIS was designed using existing cutting edge parachute technology combined with paragliding technology and innovative testing methods. This HGR is a 380 ft^2, 17-cell canopy which can be deployed at altitudes up to 25,000 feet and has a glide ratio of approximately 6:1[91]. The greatest attainable offset for a HAHO jump is determined by two factors: 1) the glide ratio of the canopy 2) the winds encountered while under canopy. According to the research done by Para-Flite Inc., an insertion team deployed at 25,000 feet and using PARIS can travel 40 kilometers without factoring in wind effects and with favorable winds this range could be extended to 75 kilometers.[92]

[91] This means that the canopy can glide 6 feet forward for every foot of altitude loss.

[92] "Para-Flite Inc. PARIS," http://paraflite.com/PARIS.htm (accessed August 21, 2007).

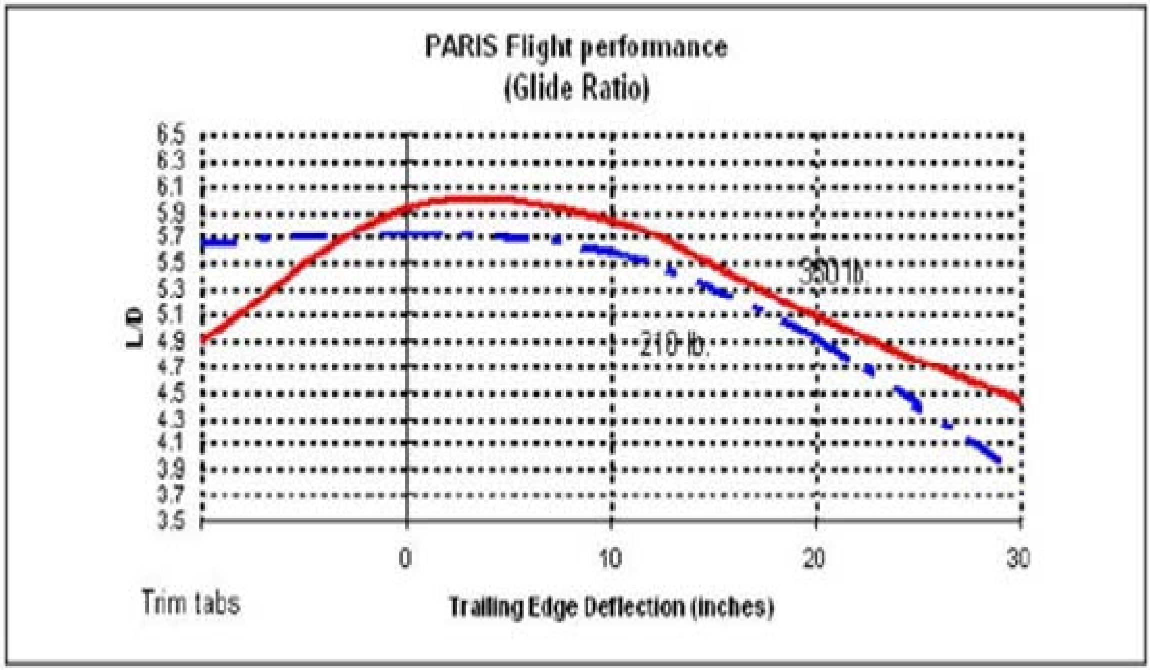

Figure 15. Chart showing the Glide ratio of the PARIS at different loadings and different trim. From[93]

While the increased glide ratio of the HGR definitely improves on existing HAHO tactics, the capability of being able to use the same equipment for exfiltration seems to have much potential for not only improving tactics but changing them.

The HGR is essentially a paraglider designed to be deployed like a parachute. A paraglider is launched from the ground by using relative wind to inflate the canopy (wing) and once inflated develops lift to get and stay aloft. This relative wind can be produced in zero or light winds by running forward with the canopy behind or in a breeze by allowing the wind to inflate the canopy. Just as with any flying wing, there are three forces acting on it:

93 "Para-Flite Inc. PARIS," http://paraflite.com/PARIS.htm (accessed August 21, 2007).

Lift, which holds the wing up; drag, which holds the wing back; and weight, which pulls the wing down by gravitational force. For a paraglider to overcome drag it is necessary for the wing to fly slightly downhill using the force from the gravity to keep the wing flying. However, this does not mean that the wing will always be flying down relative to the ground. As long as the airfoil is penetrating the relative air, speed and hence lift can be developed. The technique of flying a paraglider involves flying in air that is rising faster than the glider is dropping. This is how altitude is gained while flying any glider.[94]

Ascending flight is achieved by two major factors: 1) “thermals” (rising air) 2) “waves” (air developed by deflected wind). The details of the atmosphere and how weather is created is beyond the scope of this thesis, but the basics of these phenomena will be addressed so the concept of ascending flight with a paraglider can be understood.

If the earth heated evenly everywhere, the atmosphere would be stable and air would move very little. However, the Earth is composed of surfaces as different as water compared to land and as slight as grass fields compared to forests. These surface differences allow for uneven heating by the Sun. Thermals and wind develop by this uneven heating. As the Earth is heated by the Sun, heat radiates back into the air, causing the air to warm from the ground

[94] David Cook Sollom Matthew, *Paragliding : From Beginner to Cross-Country* (Marlborough: Crowood, 1998), 10.

upwards. As the air warms up, it becomes less dense and rises, allowing cooler air to fill in where the air was and the process continues.

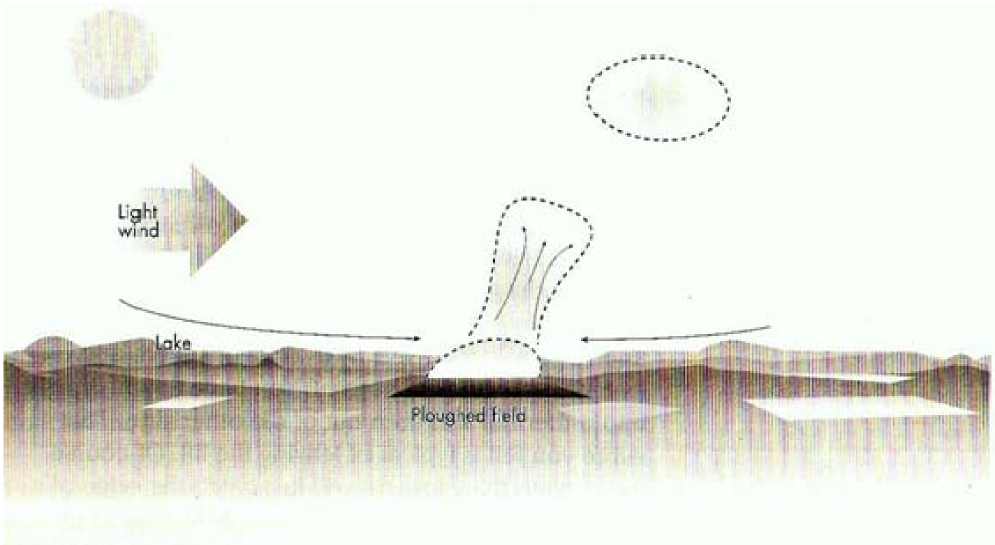

Figure 16. Thermal being radiated from a ploughed field. From[95]

This is generally how thermals are created.[96] Other variables causing global airflow include:

- Because the planet revolves, some parts of the Earth are being heated while others are being cooled.
- Not all the sunlight aimed at the Earth gets to the surface (clouds cause much of it to be reflected).
- The spinning of the Earth produces friction between the ground and the surface air layer.[97]

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95 Whittall, *Paragliding: The Complete Guide*, 105.

96 Ibid., 80.

A wave is produced by the wind being deflected over a range of hills or mountains and can be greatly amplified by a second ridge of hills.[98]

The practicality of using thermals to gain altitude involves finding the thermals and staying in them long enough to develop enough lift to carry the glider to an altitude high enough to get to the next thermal or to the ultimate destination. Finding thermals can be difficult without extensive micrometeorology knowledge. This ability to find a thermal starts with the knowledge of what types of ground develops the most lift. Freshly plowed fields, black asphalt, or a neighborhood of black roofs are obvious signs of where thermals will be created on a sunny day. Other indicators include debris in the air flowing upward and the most common indicator of all: clouds. Cumulus clouds often mark the top of thermal.[99] Turbulence is also an indicator that one has entered a thermal, although using this as an indicator would be after the fact and not something on which an operator can rely.

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[97] Whittall, *Paragliding: The Complete Guide*, 81.

[98] Ibid., 92.

[99] Ibid., 110.

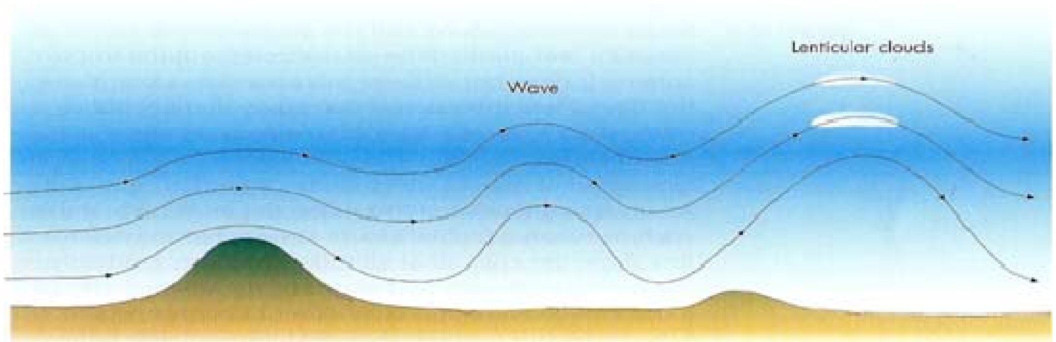

Figure 17. A series of ridges can amplify a wave and be utilized to develop lift. From[100]

The usefulness of using waves for altitude climb is more limited than the use of thermals. The main limitation is that paragliders do not fly fast enough to utilize major wave systems where the wind may be blowing at 40-50 mph.[101] Nevertheless, the milder wave effect can be used. This milder wave can be found on a hill with similar ridges upwind. The amplified wave from the series of ridges can produce significant lift.[102]

4. Any Military Application?

This system has obvious application for SOF. Not only does the HGR increase the capability of HAHO insertion but it also may provide a viable means for exfiltration. This is one innovation that has already been adopted by U.S. Forces, although its application is very limited.

One company that provides cutting edge parachute equipment for the U.S. military, including the PARIS, is

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[100] Whittall, *Paragliding: The Complete Guide*, 93.

[101] Ibid., 93.

[102] Ibid., 117.

Airborne Systems (formerly known as Para-Flite Inc.). Aaron Mebust is the vice president for sales at Airborne Systems and said that the United States Marine Corps is the biggest user of the PARIS. In an interview with *Special Operations Technology*, Mebust states, “The Marines often have to jump from helicopters, which cannot fly as high as fixed wing aircraft. PARIS allows them to fly farther distances even when they jump from lower elevations.”[103]

5. Limitations and Shortfalls

The HGR parachute requires little if any more training to be employed in HAHO. However, if the parachute was going to be used for exfiltration by ground launching, the training required would be very involved. Not only would the operator need to be knowledgeable of micrometeorology but would need to be an experienced paraglider pilot.

In addition, exfiltration with this system would not be quick or simple. Even at a max glide the paraglider or HGR has a relatively slow forward speed of 15 to 20 knots maximum, not considering a head wind or tailwind.[104] In addition, forward speed is sacrificed to gain lift.[105] This concept would be highly weather dependent and may not be practical except during daylight hours. Flying a paraglider after the sun goes down presents difficulties that may be insurmountable. There are fewer thermals after sunset, the

[103] Patrick E. Clarke, "Higher Up and further Out," http://www.special-operations-technology.com/article.cfm?DocID=2167 (accessed October 18, 2007).

[104] David Cook Sollom Matthew, *Paragliding : From Beginner to Cross-Country* (Marlborough: Crowood, 1998), 39.

[105] Noel Whittall, *Paragliding : The Complete Guide* (New York: Lyons Press, 1995), 29.

few that are available would be hard to find, and the air often sinks after sunset as it cools.

The limitations for this canopy are few when used for HAHO. However, when used for exfiltration the HGR has some significant shortcomings. Nevertheless, the HGR designed and marketed by Airborne Systems appears to have capabilities from which SOF could benefit. After all, the U.S.M.C. has already recognized this and procured them.

D. FIXED-OBJECT PARACHUTING, OR BASE JUMPING

People have been parachuting for hundreds of years, long before the advent of the aircraft and even the Montgolfier brothers' balloon flight in the late 1700s.[106] The earliest form of parachuting, from surfaces such as the tops of buildings and cliffs, is now known as fixed-object or BASE jumping.

Although most parachuting today is done from aircraft, over the years many people continued to jump from fixed objects, usually using the same techniques and equipment that were developed for aircraft jumps. While most of these leaps were successful, many were not. Evidently, two main factors contributed to the failures. First, the jump altitudes were generally at the low end of the spectrum. Second, in many cases, there was not only ground below the jumper, but also behind him. These situations provided less margin for error.

Gradually, the techniques and gear designed specifically for fixed-object parachuting have been

[106] Joseph and Jacques Montgolfier are considered the first to achieve manned flight with their "Montgolfiere" balloon. In 1783 they launched a hot-air balloon with two human passengers.

improved, and today several thousand parachutists around the world jump routinely from buildings, antennas, bridges, smokestacks, towers and cliffs. The development of better procedures and equipment was accomplished by the pioneers in the field, a few small companies, and some very hard-core jumpers. As a result, fixed-object jumping has become much more practical and could be useful for SOF.

To date, airborne infiltration is always done via aircraft, but the concept of exfiltration by parachute has never been applied. The military's experience with fixed-object jumping has been limited to the same parachute-training towers that are used for developing the basic skills of static line parachuting. However, in light of recent shifts in the environment of warfare, this sort of capability may be necessary in the future. If not fully explored, fixed-object parachuting's military potential will never be known and a novel tactical capability could be lost.

1. History and Background

Historians believe that parachuting has existed for nearly 1,000 years. The Chinese apparently experimented with rigid, umbrella-like, canopies around 1000 A.D. One of the first recorded canopy designs is Leonardo da Vinci's late 15th century drawing of a pyramid shaped "parachute." Although very few people believe that da Vinci ever tested his parachute, a century later, his countryman Fausto Veranzio built a similar parachute and reportedly used it to jump from a tower in Venice.[107]

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[107] Dan Poynter, *Parachuting: The Skydiver's Handbook*, ed. Para Publishing, 6th ed. (Santa Barbara, CA: Para Publishing, 1992), 82.

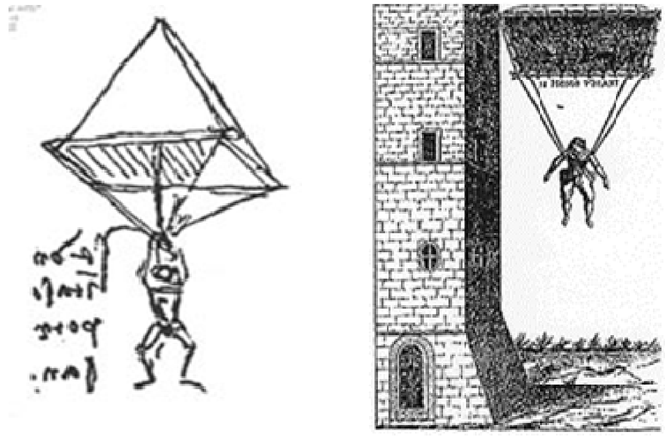

Figure 18. Leonardo da Vinci and Fausto Veranzio’s canopy designs from the 15th and 16th centuries, respectively, left to right. From[108]

These initial canopy descents were sporadic and conducted either for entertainment or as a means to escape a building. Then came the innovation of aircraft in the late 1700s, and with the further expansion of its use into the 20th century, the need for a means of emergency exit soon became obvious. As parachutes became a much-needed lifesaving device for aviators, their development expanded.

Although the evolution of parachutes during this period involved only parachutes used in conjunction with aircraft, people continued, albeit rarely, to jump from fixed objects. On February 3, 1912, the “New York Times” published a story about a steeplejack named Frederick Law who had parachuted from the hand of the Statue of Liberty dragging a round parachute behind him. He landed unharmed

[108] Jim Bates, "Parachutes," Aero.com, http://www.aero.com/publications/parachutes/9511/pc1195.htm (accessed November 1, 2007).

near the water’s edge less than 230 feet down.[109] On a summer day in 1966, using military-surplus parachutes, Mike Pelkey and Brian Schubert jumped from El Capitan in Yosemite National Park. Both men sustained injuries that they later attributed to their equipment. As Pelkey said, “In retrospect we probably should have waited until the ram-air type parachutes were invented.”[110] In 1975, Owen Quinn made history by being the first to jump from the World Trade Center. His leap was captured on film by his friend Mike Sergio and the portrait was named “The Point of No Return.” Although “square” parachutes had been developed, Quinn used a round canopy. He landed unharmed but was quickly arrested by the police.[111] While these men were the forerunners of what fixed-object jumping has become, they all used gear and techniques that had been designed for jumping from aircraft.

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[109] "Parachute Leap Off Statue of Liberty," The New York Times, http://query.nytimes.com/mem/archive-free/pdf?_r=1&res=9B03E7DA173CE633A25750C0A9649C946396D6CF&oref=slogin (accessed November 1, 2007).

[110] "About BASE Jumping- the History of BASE Jumping," http://www.baseclimb.com/BASE_history.htm (accessed November 2, 2007).

[111] C. J. Sullivan, "Twin Tower Fall," http://newyorkpress.com/15/22/news&columns/bronx.cfm (accessed October 31, 2007).

Figure 19. “The Point of no Return” Owen Quinn jumping from The World Trade Center in 1975. From[112]

More recently, there have been numerous pioneers in recent fixed-object jumping, but the man most responsible for its continued popularity is Carl Boenish. In the late ‘70s and early ‘80s, Boenish, an experienced skydiver and innovative cinematographer, introduced modern ram-air parachutes and applied specific techniques such as tracking[113] to the sport. He is best known for making a spectacular film in 1978 about the first El Capitan jumps to occur since Pelkey and Schubert’s 12 years earlier. It was so compelling that hundreds of jumpers all over the world came to the United States to make the same jump.

Boenish coined the term “Building, Antenna, Span, and Earth” or BASE, an acronym roughly defining all the objects

[112] "Owen Quinn July 22 1975 Jumps from World Trade Center Tower #1," http://www.dropzone.com/photos/Detailed/Personal/Owen_Quinn_July_22_1975_jumps_from_World_Trade_Center_Tower_1_104810.html (accessed November 5, 2007).

[113] Tracking entails a jumper getting into a certain body position that causes the jumper to move horizontally in free fall. In skydiving, this enables jumpers to get separation from other jumpers before deploying their parachutes. In fixed object jumping it allows the jumper to get separation from the object they are jumping from.

from which a person could jump. He also designed a numbering system for fixed-object jumpers, according to which a jumper “earned” his BASE number after he had made a jump from each of the four categories.

The early 1980s saw an increase in the number of fixed-object jumps conducted. For example, over a period of nine weeks in 1980, 372 jumps were made from Yosemite’s El Capitan.[114] Although they were starting to modify gear, those jumpers were still using “skydiving” equipment. Jumps were now being made from much lower altitudes than El Capitan’s more than 3,000-foot elevation, and thus the gear and techniques had to become more specifically designed for the lower altitudes to be successful. Many jumpers started using Pilot Chute Assists (PCA)[115] and removing the reefing systems (deployment bags and sliders)[116] to ensure a faster opening during their sub-terminal[117] descents.

The late 1980s and early 1990s saw the most progress in the evolution of BASE gear, as several companies emerged that developed and manufactured gear made specifically for this type of jumping. An article written in 2001 by Robin Heid for the Parachute Industry Association (PIA) focused on four of those companies. All the companies he reported on were American and included: Basic Research, Consolidated

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[114] *About BASE Jumping- the History of BASE Jumping.*

[115] A Pilot Chute Assist (PCA) involves an assistant holding the jumper’s pilot chute until their parachute has come out of the bag and the suspension lines have reached full stretch.

[116] According to USPA, a slider is a device which controls a canopy’s inflation by progressively sliding down the suspension lines during inflation.

[117] Terminal velocity is not reached (or not reached fast enough) in lower altitude jumps.

Rigging, Gravity Sports Limited, and Vertigo Base Outfitters.[118] Some of the companies have since dissolved and some have been absorbed into other companies. But there are still numerous companies that provide cutting-edge innovation in gear and techniques for fixed-object jumping. Thus, the learning curve has continued its steep ascent in regard to the developments in gear and achievements attained in this form of parachuting.

In recent years BASE jumping has exploded and thousands of such jumps are made worldwide every year. In the United States some of the most popular places are off-limits because of laws prohibiting BASE jumping. However, there are numerous legal spots and events both in the U.S. and throughout the world. One such event is “Bridge Day” in West Virginia, where jumpers have been leaping from the 876-foot-high single-span New River Gorge bridge since 1979.[119] Ever since the mid-1980s, with the exception of 2001,[120] 300-400 jumpers have shown up every year from around the world for only six hours of legal jumping off this bridge.[121] There are other places in the United States, such as the Perrine Bridge in Idaho, where reports claim BASE jumpers make hundreds of jumps each year. On a normal summer weekend, as many as 100 jumpers can be found jumping from the 486-foot-high “Potato Bridge,” as it is referred

[118] Robin Heid, "Low Altitude Gear Comes Out of the BASEment," http://www.pia.com/PNB/PNB-2000-12.PDF (accessed November 2, 2007).

[119] On August 1, 1979, Burton Ervin became the first man to jump off the New River Gorge Bridge.

[120] After the events of September 11th,the Bridge Day Coordinator made the decision to not hold the event.

[121] "Bridge Day -BASE Jumping Registration," http://www.bridgeday.info/ (accessed November 6, 2007).

to by jumpers. The Perrine Bridge is a legal jumping spot, and the local community has embraced these athletes, with stores even giving discounts to BASE jumpers.[122]

But fixed-object parachuting is not limited to the U.S. Indeed, some of the largest events are held abroad. Malaysia, for instance, has an event every year during which various buildings are opened for BASE jumping. In August of 2007, over a three-week period, 2,780 BASE jumps were made from five different buildings.[123]

2. Major Differences Between Fixed-Object Parachuting and Parachuting from an Aircraft

Some may think that parachuting is the same whatever the particular jump platform. After all, until the late 1980s, most of the gear used for fixed-object jumping was simply skydiving gear that may or may not have been modified. But modern pioneers figured out that there are numerous major differences between the two forms of parachuting,[124] the most obvious being the height above the ground from which a jump takes place. While some BASE jumps, such as El Capitan, or Kjerag in Norway, are as high as many skydives, that is, more than 2,000 feet, most fixed-object jumps are done from much lower altitudes, 1,000 feet or less. A jump’s height is crucially important because there must be enough time for the canopy to

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[122] Adam Tanner, "Idaho Town Becomes Mecca for BASE Jumpers," http://www.bridgeday.info/legal365.php#2005-08-22 (accessed November 5, 2007).

[123] "KL Tower International BASE Jump," http://www.kltowerjump.com/about.html (accessed November 6, 2007).

[124] This section in not meant to be an all inclusive “How to” in BASE jumping but an overview of some of the major differences. There are many differences which should be addressed should the innovation be adopted.

inflate, for the jumper to set up and land in a controlled fashion, and/or, if a malfunction occurs, for the jumper to react. The height of a jump can be compensated for in several ways. One method involves using a larger pilot chute (PC) to extract the main canopy faster during shorter delays. The larger PC will extract the main canopy during a sub-terminal deployment. Pilot chute selection is vital to making a successful BASE jump. Some in the BASE community have developed parameters for choosing the correct PC, which is usually determined by the delay. Another involves

Figure 20. Chart produced by Basic Research showing what type of PC and slider recommended for a given altitude or delay. From[125]

[125] "Delay Chart," http://www.basejumper.com/Articles/Jumping/Delay_Chart_706.html (accessed November 8, 2007).

the packing procedures used for the canopy: packing with the slider[126] down or removing the slider entirely allows a much faster opening during shorter delays. Another solution involves pilot chute assist or a static line to extract the canopy on exit.

Sub-terminal exit, descent, and parachute deployment comprise another major difference. Although it is associated with the height from which such jumps are made, it is a separate factor in and of itself. A jumper who leaves an aircraft already has some speed built up due to the forward airspeed of the craft, even though at exit the jumper is generally not at terminal velocity (TV).[127] When a jumper falls at or near TV, he can maneuver his arms and legs aerodynamically to control his body. In fixed-object parachuting, jumpers start out at zero speed and therefore must control their bodies gymnastically until they accelerate to a fast enough airspeed that they can control their bodies aerodynamically.[128] Most parachutes are designed to open at terminal velocity. But during many fixed-object jumps (<1000 feet), a jumper will not reach TV prior to opening his parachute. Thus, a BASE-specific canopy must be configured differently than a typical ram-air canopy. One such design variation includes a feature

[126] According to USPA, a slider is a device which controls a canopy's inflation by progressively sliding down the suspension lines during inflation.

[127] According to Webster's dictionary, terminal velocity is the velocity reached by a falling body when the frictional resistance of the enveloping medium (air) is equal to the force of gravity.

[128] Tom Begic, "Differences between B.A.S.E. Jumping and Skydiving," http://www.basejumper.com (accessed October 26, 2007).

known as secondary inlets, usually one-way vents[129] in the bottom skin of the parachute, located in the forward third of the canopy. The vents serve the important purpose of accelerating the inflation of the canopy on sub-terminal parachute deployments.[130]

Another significant difference between jumping from fixed objects and jumping from aircraft involves the proximity of obstacles that must be avoided on the way to parachute deployment and landing. Not only is the object from which you are jumping from an obstacle, so are other buildings, rock formations, or structures that must be cleared. When exiting from an aircraft, there is generally plenty of space and other jumpers are all that must be avoided. This is not the case with fixed-object jumping. For this reason, site reconnaissance and selection is crucial. The preciseness of the exit point of a BASE jump is critical because exiting a few feet either way from a clear point may not be safe. There may be some sort of unseen protrusion. Separation from the launch object must be obtained and maintained through a stable exit and a positive track away from the object.

An off-heading[131] opening on a BASE jump can have a detrimental outcome. For this reason, packing procedures

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[129] Early vented canopies did not have one-way vents which prevent air from spilling out of these openings. As a consequence of the air passing both ways through the vents of the early vented canopies, the canopy had a lower glide ratio and poor flare.

[130] Tom Aiello, "My First BASE Rig," http://snakeriverbase.com/MyFirstBASERig.pdf (accessed November 8, 2007).

[131] An off-heading opening is where the parachute opens and begins to fly in a different direction than the jumper intended and/or anticipated.

that improve on-heading opening performance are very valuable. Some manufacturers have adopted other design features that reduce off-heading openings. One such feature is multiple bridle attachment points. Most parachutes have only one attachment for the bridle that connects the PC to the main canopy and that is at a point in the middle of the center cell. Multi-bridle attachments are four lines that attach to separate points on the canopy: one in the usual spot, one near the back of the center cell, and one each in the middle of cells three and five. Multi-bridle attachments can increase the percentage of on-heading openings.[132]

The last difference we will discuss involves the landing area. Most BASE jumps have tight landing areas with few “outs,” so accurate landings are vital. Although precise landing is important with any jump, when jumping from fixed objects an accurate landing can make the difference between life and death. BASE canopies are designed for accuracy, hence additional features have been added to BASE parachutes to provide a safe landing in a small spot. Secondary inlets with one-way flaps provide an added value for jumps in which descent is in or near a stall. This modification helps prevent the canopy from deflating and collapsing when the canopy stalls or the nose inlets are pinched off during an object strike.[133]

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[132] Tom Aiello, "My First BASE Rig," http://snakeriverbase.com/MyFirstBASERig.pdf (accessed November 8, 2007).

[133] BASEWiki, "BASE Canopies," http://www.basejumper.com/Articles/Gear/BASE_Canopies_681.html (accessed November 8, 2007).

The differences between fixed object jumping and parachuting from aircraft are many. This discussion only scratches the surface. At this point, it is important to note that the solutions discussed here are far from the only ways to meet these challenges. If SOF were to adopt fixed-object jumping, all of the differences would need to be addressed.

3. The Controversy

As with jumping from airplanes during the early days of sport parachuting, jumping from fixed objects is somewhat controversial, particularly in the United States. The stigma which surrounds BASE jumping is not unfounded. Many of the buildings and natural structures that are prime BASE objects in America are usually off-limits to these jumpers and laws have been broken in the past by sometimes irresponsible people determined to jump. However, most BASE jumpers are not “suicidal outlaws;” they are skilled adventure athletes who have cultivated sufficient knowledge and skill to make the high risk of fixed-object jumping a calculated and acceptable risk.

There is no denying that BASE jumping is a dangerous activity. And due to the “underground” nature of many of the jumps, gathering statistics for the sport is difficult. While there is no way of knowing exactly how many fatalities have been associated with this sport, the statistics from some of the events where records were kept gives us some insight as to the level of risk. Take Bridge Day in West Virginia, for example. Since 1981 there has been an average of 600 jumps per year, resulting in three

fatalities,[134] a ratio of one death every 5,000 jumps. In Norway, the Stavanger BASE Klubb keeps records of the rescues and fatalities at Kjerag. Since 1994, there have been 26,203 jumps with nine fatalities reported,[135] a ratio of 1:~3000. In skydiving, the death rate is easier to track because parachute centers more precisely record and report jump numbers and fatalities. The fatality ratio for skydiving is reported to be one every 70,000 jumps,[136] which illustrates how much more dangerous fixed object jumping is in comparison. However, as in any dangerous activity, the risks can be managed and minimized. After all, during the early years of aircraft, flying was also considered excessively dangerous.

As discussed, all of the innovative advancements in fixed-object jumping have been developed by small companies and individuals who worked to minimize the fatality rate. There is no regulating authority[137] for BASE jumping; the lessons learned are typically passed by word of mouth. Although there are websites and articles in which the “experts” share their knowledge, no standard document for training and procedures as yet exists. If SOF were to adopt this capability, an extensive compiling of information would be necessary.

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[134] Robin Heid, RE: BASE Stats, 2007 (accessed November 12, 2007).

[135] "Statistics," http://www.basekjerag.com/rogaland/stavanger/svg_base.nsf/id/2CC0E47A17AB6173C1256E150002B1F9?OpenDocument (accessed November 8, 2007).

[136] Robin Heid, RE: BASE Stats, 2007 (accessed November 12, 2007).

[137] The author does not intend to imply that a regulating authority is good, bad, or even possible; only that the lack of one could explain some of the inconsistencies among jumpers knowledge and thus the increased risk.

4. Any Military Application?

Although fixed-object jumping would probably not be a good method for inserting hundreds of troops onto the battlefield, BASE jumping may have some application in the unorthodox warfare of the future. If Arquilla and Ronfeldt are correct in their projections about the next era of warfare, fixed-object jumping could play a significant role in “omni-directional yet well-timed assaults.”[138] Many domestic and foreign cities have the kind of urban terrain that would make BASE jumping a logical and practical option. Clearing a building from the ground up, as opposed to from the roof down, could require the use of BASE gear and techniques for the operators to exfiltrate. This sort of exit could be planned from the beginning or used as a backup strategy. Another useful application of BASE might be to enhance mobility from the top of a building, peak, or bridge. Fixed-object jumping in conjunction with wing suits to get further separation from the enemy would provide an expanded capability.[139]

5. Limitations and Shortfalls

The specialized training and equipment would be a big hurdle for adopting BASE jumping. However, numerous first jump courses (FJC) that already exist could be used as a model. The training could also be outsourced to companies such as Snake River BASE Academy[140] located in Twin Falls,

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[138] Arquilla, John. Ronfeldt, David F. and others, *Swarming & the Future of Conflict*, vii.

[139] However, the experts say that a wingsuit BASE jump from anything less than 1000 feet would be of no advantage.

[140] "Snake River BASE Academy," http://snakeriverbase.com/ (accessed November 7, 2007).

Idaho; Apex BASE,[141] Located in Perris, California; and Asylum Designs,[142] located in Auburn, California. The level of parachuting experience required for operators would have to be high before they started BASE-specific training. Most courses require a minimum experience of 100 jumps and the necessary canopy skills prior to starting the course. Although there is no data on how many military personnel already BASE jump, there is a pool of experience on which to draw.

Several gear manufacturers already exist and would only need prompting to create the necessary equipment. Backup systems such as reserves are not normally used in BASE jumping, but there are systems available that are built with a reserve.[143] There is a possibility that a ballistic reserve that deploys rapidly could be designed, but very little research has been done in that regard.

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141 "Apex BASE," http://www.apexbase.com/portal/ (accessed November 13, 2007).

142 "Asylum Designs," http://www.asylumbase.com/Asylum_Frames.htm (accessed November 13, 2007).

143 Aiello, *My First BASE Rig*

Figure 21. Ted Strong and Robin Heid making the first tandem BASE jump at New River Gorge in 1984. From[144]

One limitation of BASE jumping for military use is the small amount of gear that a jumper can take with him. Although at least one tandem BASE jump has been performed, BASE jumpers don’t usually take much gear or another person with them. Some manufacturers do make BASE rigs with storage for things such as camping gear. In any case, the requirement for gear may not be a problem if BASE is used for exfiltration or evasion. Another limitation has to do with winds. As in any parachute jump, winds can restrict and/or prevent the use of this capability. In urban environments especially, because of the funneling by the surrounding structures, winds are extremely tricky.

Again, BASE jumping is dangerous and this report does not mean to imply differently. However, when and if the need for this capability arises, the primary way to

[144] "Ted Strong and Robin Heid's Tandem BASE Jump 1984," http://www.mywvhome.com/bridge/Bridge2/tedstrong.htm (accessed November 13, 2007).

minimize the risk is to have people who are trained. This is not a capability, however, for which the optimum development will happen overnight. After all, parachuting from aircraft was extremely dangerous when it was first adopted, and the extremely risky jumps the first paratroopers experienced could easily be compared to BASE, or fixed-object, jumps.

E. TANDEM PARACHUTING

While many of the innovations covered in this report require extra training and specialized equipment, this innovation delivers "more for the money." Not everyone who needs to go behind enemy lines has the skills that some of these insertion methods require. With tandem parachuting, more operators, equipment, and necessary assets can be inserted via parachute for only a little more training and cost. Tandem involves one trained operator capable of carrying extra passengers or assets. There are systems available in which equipment is precisely inserted via a parachute with no operator (for operations such as humanitarian relief). These separate systems have obvious advantages but this study focuses on systems involving a trained operator jumping in tandem with a person, animal, or other assets.

The concept of tandem parachuting has been recognized as viable and has already been adopted by some elite U.S. military units. Although currently in use, there still exists a lack of knowledge about and acceptance of tandem systems. This section will give an overview of the current applications as well as some emerging uses of this concept.

1. History

Tandem parachuting originated with civilians wanting to share the thrill of their sport with wives, girl friends, and even children. Although there are a few reports of tandem skydives being made in the 1970s, most argue that tandem parachuting didn't emerge until the early 1980s. Two men, Ted Strong and Bill Booth, living in Central Florida, developed systems for safely and comfortably conducting tandem skydives. Although Strong and Booth were friends and shared ideas, the systems they created were not joint ventures.[145]

Strong is considered the first to successfully develop and market the current[146] system for taking passengers through a free fall and canopy ride without the passenger possessing any special skills or training. In November 1982, Ted Strong and Bill Morrissey set out to engineer a tandem system made specifically for this type of jumping. After a few months of design and redesign, Strong felt he had a prototype that met the criteria. Then, in 1983, Strong and one of his employees, Ricky Meadows, made their first tandem jump with the newly designed equipment. In September 2005, Strong discussed the early days of tandem skydiving in an interview with skydiveradio.com.[147] In this interview, he reminisced about the first system he

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[145] Ted Strong, "SKYDIVERADIO.COM," Skydiveradio.com, http://mediacloud.libsyn.com/skydiveradio/sr8_09_27_05s.mp3 (accessed September 13, 2007).

[146] The current tandem system uses a drogue parachute. Booth actually marketed his system first but without a drogue and Strong waited to market his after he had developed the drogue system.

[147] Ted Strong, "SKYDIVERADIO.COM," Skydiveradio.com, http://mediacloud.libsyn.com/skydiveradio/sr8_09_27_05s.mp3 (accessed September 13, 2007).

designed. This system included a harness for the passenger that was attached to the instructor’s harness, a ram air parachute for the main canopy, and a 26-foot low-porosity round parachute for the reserve. However, there was no drogue[148] parachute, which resulted in many hard, parachute damaging openings and jumper fatigue. Strong soon discovered that the free fall rate had to be slowed down. Adopting the drogue parachute for this system slowed the fall rate, providing the tandem pair a safer, more comfortable opening.

After a few years of refining his product, Strong was finally issued patent #4,746,084 for his system in 1987.[149] This is basically the same system used today and can be found on many DZs around the world. Ted Strong is the owner of Strong Enterprises in Orlando, Florida.

Bill Booth began marketing his system without a drogue parachute, but after Strong introduced its drogue-based system, Booth followed suit. Booth resisted using a drogue parachute on his tandem system because he didn’t want to complicate it. Booth believed that developing a canopy that could withstand the opening shock was the answer. However, in the end, he also adopted a drogue for his system.[150] Booth is well known for many of his parachuting inventions

[148] As defined by USPA, a drogue is a “trailing drag device used to retard the movement of an object through the air, used in skydiving to regulate the fall rate of tandem skydivers.”

[149] Strong Enterprises, "Tandem Equipment," www.strongparachutes.com, http://www.strongparachutes.com/Pages/tandem_main.htm (accessed September 13, 2007).

[150] Bill Booth, "Skydiveradio.Com Broadcast #16," SKYDIVERADIO.COM, http://mediacloud.libsyn.com/skydiveradio/sr16_11_22_05s.mp3 (accessed September 19, 2007).

such as the three-ring release[151], hand deployed pilot chute, and his “Skyhook” Reserve Static Line (RSL)[152]. These innovations have transformed skydiving, making the sport safer than ever would have been possible without them. Currently, Booth and his company, United Parachutes Technologies, LLC produce one of the safest and most reliable tandem systems on the market.

Tandem skydiving started as a means to provide someone a parachute ride without having to be trained. Since then, tandem parachuting has been incorporated into training programs for first jump courses as well as a “one-time ride” for people either not interested in being trained or not capable due to a physical limitation. Recently, the military application of passenger tandem has been exploited.[153]

Military jumpers have been taking equipment with them since the very first soldiers started jumping because soldiers need weapons and gear to carry out their missions. However, this capability has evolved and continues to develop. In the early years of U.S. airborne, drops of equipment bundles separate from the soldier were predominant. Around 1950, the idea of dropping the soldier

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[151] As defined by USPA, a three-ring release is a type of single point release invented by Bill Booth. The system is based on three interlocking rings on each riser held in place by a small loop that is retained by a cable. Pulling one handle releases both main risers simultaneously or nearly simultaneously.

[152] A RSL is attached to the risers of the main parachute and is designed to activate the reserve parachute when the malfunctioned main canopy is jettisoned. The Skyhook uses the deployed malfunction as a pilot chute for the reserve dramatically decreasing the distance and time it takes for a reserve canopy to open.

[153] Patrick E. Clarke, "Higher Up and further Out," http://www.special-operations-technology.com/article.cfm?DocID=2167 (accessed October 18, 2007).

with his gear attached became more common.[154] There were several reasons for this concept shift. First, the difficulties associated with the soldier having to locate and then unpack the container before he was ready to fight were a decided drawback. Other impediments included: the equipment never getting released (i.e. the men get out, but the equipment goes down with a stricken aircraft, or the aircrew simply didn't drop the equipment); collision of the equipment drop with men still in descent or on the ground; or the equipment falling into enemy hands.[155]

2. What Tandem Includes and Involves

Tandem systems developed in recent years include capabilities for carrying personnel, equipment, vehicles, and assets such as Military Working Dogs (MWD). While some of these assets may be inserted separately, there are many advantages to inserting them in tandem with a skilled operator. These advantages include:

- The ability to insert assets less than capable of parachuting by themselves (i.e. animals or untrained but necessary personnel)
- Immediate access to necessary equipment for the operator
- In the case of ready-use vehicles, immediate further mobility upon landing
- Reduced possibility of the enemy reaching equipment before the operator

Tandem passenger insertion is a proven concept. There are several systems designed for this and available on the

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[154] John S. Weeks, *Airborne Equipment : A History of its Development* (New York: Hippocrene Books, 1976), 51.

[155] John S. Weeks, *Airborne Equipment : A History of its Development* (New York: Hippocrene Books, 1976), 55.

market. The concept is not only proven, but safe; more than one million civilian tandem skydives are made each year[156] and very few, if any, of the skydiving fatalities, which occur annually, involve tandem parachuting.[157]

3. Capabilities and Potential of Tandem Parachuting

Although passenger tandem parachuting is a capability some units possess, there are more possible military applications.

a. Passenger Tandem

Passenger tandem involves insertion of a passenger who is critical for an operation, but not individually capable of this sort of infiltration. For example, an informant, scientist, or otherwise skilled person could be required at an objective and air insertion by parachute is the only option. If there is no time to train the important asset, or he/she is simply unable to perform the required action of parachuting, tandem insertion would be necessary. This capability is already known to be a valuable skill. Retired Army Major Joe Andrzewski was quoted in an article out of the *Special Operations Technology* online edition as saying, “Tandem HAHO jumping allows you to take valuable experts into an operational area, say a nuclear expert or a surgeon, who

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[156] Strong Enterprises, *Tandem Equipment.*

[157] United States Parachuting Association, "Accident Statistics," USPA, http://www.uspa.org/about/page2/relative_safety.htm (accessed October 15, 2007).

have no expertise in parachute jumping.” He also went on to say that these capabilities have been used in both Iraq and Afghanistan.[158]

Figure 22. Photo of SIGMA Passenger tandem system developed by United Parachute Technologies. (Photo taken by Rickster Powell) From159

Other essential passengers may be required such as Military Working Dogs (MWD). MWDs have served as a war fighter’s asset throughout history. These animals have played an important part in conflicts such as WWI, WWII,

[158] Clarke, *Higher Up and further Out.*

[159] Uninsured United Parachute Technologies, "SIGMA Tandem Parachute System," http://www.unitedparachutetechnologies.com/index.php?option=com_content&task=view&id=14&Itemid=73 (accessed October 9, 2007).

and Vietnam.[160] DOD Directive 5200.31 delineates how dogs are used in support of the military. These missions include: scout, sentry, search and rescue, narcotics, explosives, and enemy detection.[161] Dogs possess superior senses such as: smell, vision, and hearing,[162] and these enhanced senses make them a valuable addition for the war fighter. Missions involving MWDs may or may not require a handler, but most dogs operate in conjunction with a trained handler.[163]

MWDs have been parachuting into combat since WWII. The British SAS was the first military unit to parachute dogs into combat during WWII. The U.S. followed, in 1942, when a search and rescue unit of the U.S. Army Air Corps dropped dogs, sleds, and a flight surgeon on a frozen crash site near the North Atlantic.[164] Consider also the story told by former paratrooper William Kummerer. On August 14, 1944, while attached to the 463rd Parachute Field Artillery, Kummerer made a jump into southern France as part of a “post-D-day mop-up mission.” Along with his group of 14 men a Doberman pinscher parachuted in with them. The

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[160] William H. Thornton and Army-Air Force Center for Low Intensity Conflict (U.S.), *The Role of Military Working Dogs in Low Intensity Conflict* (Langley Air Force Base, Va: Army-Air Force Center for Low Intensity Conflict, 1990), 4.

[161] Ibid., 9.

[162] "Dogs: Form and Function," Natural History Museum of Los Angeles County, http://www.nhm.org/exhibitions/dogs/formfunction/index.html (accessed October 27, 2007).

[163] William H. Thornton and Army-Air Force Center for Low Intensity Conflict (U.S.), *The Role of Military Working Dogs in Low Intensity Conflict* (Langley Air Force Base, Va: Army-Air Force Center for Low Intensity Conflict, 1990), 6.

[164] Hahn's 50th AP K-9, "K-9 History: WW II- US Canines in Combat," http://community-2.webtv.net/Hahn-50thAP-K9/K9History8/ (accessed October 15, 2007).

dog was “unceremoniously kicked out the door with a special parachute attached to a static line.” This MWD demonstrated its worth when, soon after they landed, the Doberman alerted them to some nearby and potentially mission-ending Germans.[165]

Figure 23. MWD being deployed via static line parachute during WWII. From[166]

While there is some talk of contemporary U.S. troops jumping tandem with MWDs, little information can be found on their employment. Tandem with a handler seems to have a much greater advantage than “unceremoniously” kicking the dog out the door under its own parachute. Meanwhile, Complete Parachute Solutions does provide a training program for this sort of capability as advertised on its web site.[167]

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[165] Michael G. Lemish, *War Dogs : Canines in Combat* (Washington: Brassey's, 1996), 117.

[166] Hahn's 50th AP K-9, *K-9 History: WW II- US Canines in Combat*

[167] "Complete Parachute Solutions (Training)," http://www.cpsworld.com/index.php?which=training&packageID=2426 (accessed October 15, 2007).

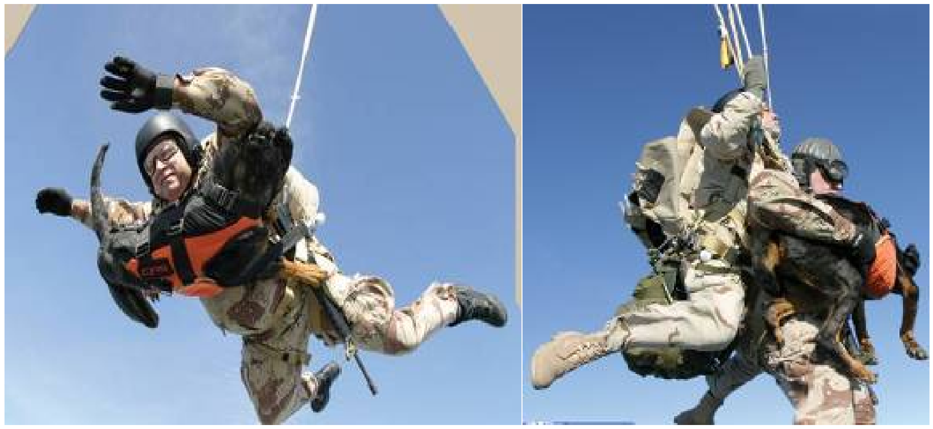

Figure 24. Complete Parachute Solutions provides training in canine parachute insertion. (Courtesy of CPS) From[168]

b. Equipment, Military Tethered Tandem Bundle (MTTB)

All MFF jumpers are trained to jump with a minimum of equipment, which includes primary and secondary weapons and a rucksack or two, because there is a limit to how much operators can carry on their person. Not only is there a weight limit; but also as more equipment is added to the body of the jumper, the complexity and risk of the jump increases.

A tandem system known as Military Tethered Tandem Bundle (MTTB) has been developed by a number of companies in recent years. This system allows an operator to carry upwards of 450 pounds of equipment in a container. This equipment is attached to the parachutist by a tether, and, although usually deployed in tandem with an operator, the

[168] "Complete Parachute Solutions (Training)," http://www.cpsworld.com/index.php?which=training&packageID=2426 (accessed October 15, 2007).

system has the capability of being deployed independently. Strong Enterprises and Butler Tactical Parachute Systems both offer such systems.

Both work similarly. The operator and the tethered bundle leave the aircraft and a drogue parachute is deployed. The drogue serves to slow the pair, and also stabilize their fall. The tethered container has a harness attached to its own parachute that is connected to the jumper.

Figure 25. MTTB can provide operators the capability of carrying much more equipment than a rucksack. (Courtesy of Strong Enterprises) From[169]

When conducting a MTTB jump, the operator has several options of delivering the bundle. The first option for bundle delivery involves the jumper releasing the equipment in free fall. The equipment would fall to a preset altitude and the bundle's AAD would then open its

[169] Michael Dusik, Subj: 6 great Iphotos, October 18, 2007.

parachute. This option is valuable, especially when a jumper experiences a malfunctioning main parachute or other problem, when jettisoning is the best option. The second option consists of the operator connecting a static line to the bundle's parachute and releasing the bundle, initiating the equipment's own parachute deployment immediately. This option would be performed after the jumper is under a fully deployed canopy and can be performed as low as 300 feet. The third choice involves simply landing his parachute with the equipment still attached. Landing with the equipment would provide the quickest access to the gear but also may not be practical due to terrain or other circumstances. The last option doesn't involve an attached operator. This alternative includes simply arming the AAD and pushing the bundle out of the aircraft.[170]

c. Ready Use Vehicles

Further mobility can be an important advantage for an operator who has been inserted via a parachute. Vehicles have been dropped in conjunction with paratrooper insertions in the past, but this was typically done separately. When done in this manner, the ground transportation needs to be located, de-rigged and set up before the operators can use it. When jumping in tandem with a "ready use" vehicle the operators simply jettison the canopy on landing and, without delay, proceed on their mission.

[170] "TT-600 Tethered Tandem Bundle Delivery System," Butler Tactical Parachutes Systems, LLC., http://www.butlerparachutes.com/ (accessed October 18, 2007).

Strong Enterprises markets a series of what it calls “Manned Airborne Vehicles.” These vehicles include: the Airborne All Terrain Vehicle (AATV), the Airborne Trailer (ATR), the Airborne Prowler, and the Rhino AATV. The AATV is a Suzuki four-wheeler that carries one or two operators. The ATR can carry four operators or one operator and up to 1,000 pounds of equipment. Upon landing, the ATR hooks to any of the other AATVs. The Rhino AATV has the same capabilities as the standard AATV with the additional capacity of carrying four operators.

The “ready use” vehicles are jumped in a fashion similar to any tandem system. The operator leaves a tailgate aircraft and a drogue is deployed. The drogue not only slows the fall rate but also stabilizes the pair. When the operator gets to the deployment altitude he releases the drogue and the drogue becomes a pilot parachute for the deployment of the main canopy. Under canopy, the operator flies the vehicle’s canopy to the objective. With these systems the operator wears his own parachute in case he needs to egress the vehicle.

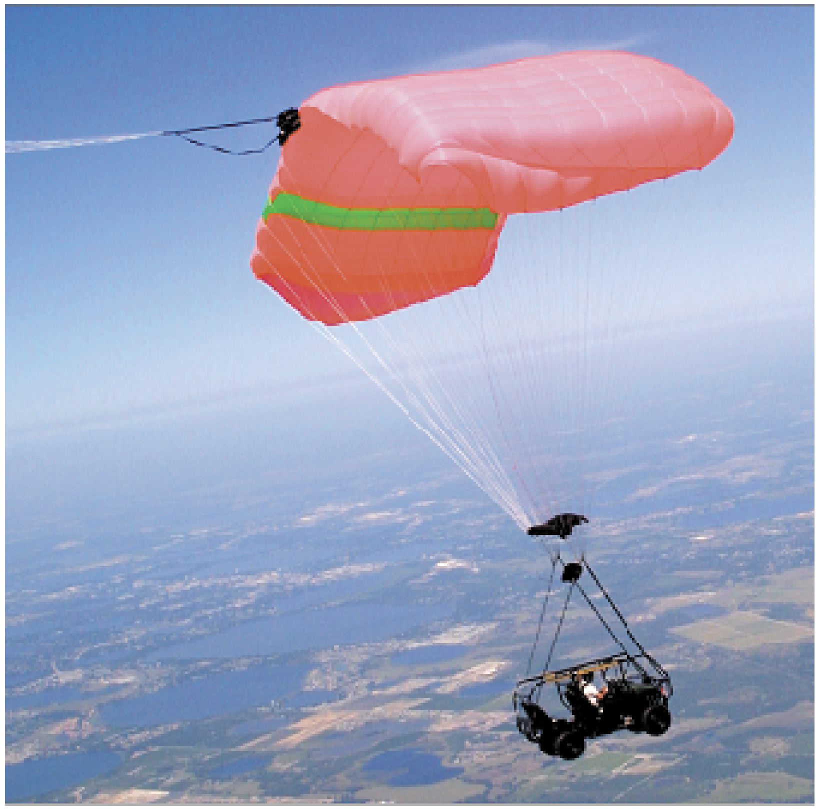

Figure 26. Airborne All Terrain Vehicle (AATV) developed and marketed by Strong Enterprises. (Courtesy of Strong Enterprises) From[171]

4. Any Military Application?

Tandem parachuting has already proven useful for many of today's military forces. The question that remains is: how much should this concept be exploited and what is its potential for further development?

The passenger tandem concept has obvious utility and will continue to be used to great advantage. Further development and training will only make it safer and more

[171] "Strong Enterprises- Military- RHINO," http://www.strongparachutes.com/Pages/mil_veh_RHINO_chute.htm (accessed October, 17, 2007).

capable. While there are precision parachute systems for getting equipment to an exact location through the use of GPS and computers flying the bundle's canopy, equipment insertion in tandem with an operator provides a usefulness which can rarely be duplicated. The "airborne" ready use vehicles provide a great advantage for forces who require immediate further mobility after insertion. This concept appears to have a lot of potential in future special operations. However, according to Strong, the only military to buy this system, so far, are the Egyptians. These vehicles could also easily be expanded to insert jet skis or snowmobiles for amphibious or cold weather operation.

5. Limitations and Shortfalls

Once again, specialized training and equipment are required for tandem jumping. For civilians to become tandem instructors, they must have 500 skydives and three years experience.[172] However, military tandem is usually less stringent and some companies such as CPS only require 200 jumps and a prior qualification as a MFF Jumpmaster to be trained in both tandem and MTTB.[173] The training required for the "Manned Airborne Vehicles," while more specialized, requires similar basic parachuting experience.[174]

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[172] Strong Enterprises, "Tandem Prerequisites," http://www.strongparachutes.com/Documents/PDF_Files/Tandemprerequisites.pdf (accessed October 22, 2007).

[173] *Complete Parachute Solutions (Training)*

[174] *Strong Enterprises- Military- RHINO*

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III. CONCLUSIONS

The Neil Armstrong quotation that begins this thesis referred in its original context to spacecraft technologies that are much more complex than parachute innovations. Nonetheless, those words resonate here as well: “Science has not yet mastered prophecy. We predict too much for the next year and far too little for the next ten.” These wings, types of canopies, and different insertion methods may not be the solution to current, immediate or future threats. Nevertheless, 25 or 50 years from now these concepts, or some variation of them, likely will be a critical tool soldiers use to insert on an offset objective, escape impending capture from a mountain top or building, or evade the enemy on the battlefield.

The development of parachutes, like the development of spaceships, began with many failures and few believers. Yet, today, almost 40 years after the first man walked on the moon, space ships and space stations are used every day for various purposes. This year (2008), Virgin Galactic space travel plans to launch recurring commercial space trips for people from all walks of life.[175] Whenever technology arrives it can be difficult to see the future applications, because, as Neil Armstrong said, “Science has not yet mastered prophecy.”

This thesis provides an overview of five parachute innovations that show considerable potential. Some have already been adopted for limited use by U.S. Special

[175] Virgin Galactic, "Virgin Galactic: WHEN CAN I GO?" Virgin Galactic, http://www.virgingalactic.com/htmlsite/overview.htm (accessed January 22, 2007).

Operations Forces; others have not yet been considered. In this concluding chapter, I evaluate the first operationalized use of HALO to make general recommendations as to if and when these innovations should be adopted. Further, McRaven's "principles of special operations" are applied to the potential implementation of these innovations.

A. RECOMMENDATIONS

Throughout history, people have resisted the adoption of technologies until the benefits of their use became obvious. Sometimes, adopting them sooner would have been better than later. Though in parachuting in recent years, both HALO and HAHO have been used successfully,[176] HALO was not implemented operationally until almost 15 years after the concept was first adopted and operators were trained.[177] The first group to operationalize the concept was the Military Assistance Command Vietnam/ Studies and Observation Group (MACV/SOG).[178] Though those operations were successful overall, they were not without problems. Nonetheless, it is largely because of that earlier adoption that the problems were overcome and HALO became a viable insertion method. The earlier adoption resulted in a pool of experienced operators who understood the potential and limitations of this method. The advanced techniques and

[176] Patrick E. Clarke, "Higher Up and further Out," http://www.special-operations-technology.com/article.cfm?DocID=2167 (accessed October 18, 2007).

[177] U.S. Army Special Forces began HALO training in 1957.

[178] John L. Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam* (New York, N.Y: Simon & Schuster, 1997), 295.

equipment they acquired through their experiences also contributed to its eventual success.

In his book *SOG: The Secret Wars of America's Commandos in Vietnam,* John Plaster wrote extensively about these first HALO missions. Because of the covertness they provided, in comparison to traditional helicopter insertion and low-level static line parachute drops, HALO operations were initiated during the war in Vietnam. At the time, an apparent Operational Security (OPSEC) leak plagued the MACV/SOG and drove the SOG Chief, Colonel John Sadler, to try a new approach for inserting his commandos. Sadler had attended HALO training in 1958, served on the Airborne Board at Fort Benning, and was considered one of the Army's "foremost parachuting experts." In 1970, he authorized the first combat HALO team, which was assembled by Sergeant Major Billy Waugh. It consisted of two Montagnards, an officer of the Army of the Republic of Vietnam (ARVN), and three Americans. It was led by Staff Sergeant Cliff Newman. Although he was not HALO qualified at the time, Newman had done hundreds of sport skydives. The other two Americans had much experience in HALO - one was a former HALO instructor - but the indigenous commandos had none. For almost two months the six men trained for the mission with the help of the best HALO instructors the 1st Special Forces Group had to offer. It would not only be the first combat HALO mission, but would also be done in the dark. Thus improvisations in techniques and gear had to be made to ensure that this and future HALO missions were successful. As Waugh points out, "We didn't have any book to tell how

to do it… we were writing the book."[179] The mission occurred on November 28, 1970.[180] Except for some problems with the insertion, including the team getting separated, the operation was a success. It proved that HALO was a useful means for entering an area undetected by the enemy.[181]

In May 1971, a second HALO mission was conducted. This team, led by Captain Larry Manes, consisted of four U.S. commandos whose HALO experience level was much higher than the previous team. However, though they used grouping techniques to stay together in freefall, they still had problems grouping together under canopy and had separated by the time they reached the ground. Upon landing, one soldier was seriously injured, when a "toe popper mine" exploded, and had to be extracted. Nonetheless, the team's insertion was determined to be "apparently undetected."[182]

The next mission, in June of that same year, led by Sergeant Major Waugh, was considered the least successful HALO mission thus far because it resulted in several injuries and a team member "missing in action." The operation was problematic from the beginning. First, the base man, who had green lights on his parachute container and canopy for the others to follow, experienced a tear in the center of his parachute. The resulting blow-out tore

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179 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 297.

180 Charles Wesley, *Special Forces, the First Fifty Years : The United States Army Special Forces 1952-2002* (Tampa, FL: Faircount LLC, 2002), 181.

181 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 301.

182 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 303.

away the canopy light and caused him to plummet to the earth with little to no canopy control. Though he suffered numerous injuries, he survived. Another team member, however, Sergeant Madison Strohlein, crashed through the trees breaking his arm and getting stuck high in the jungle canopy, separated from his teammates and unable to get down. While the other three were extracted soon after insertion, due to bad weather and problems in the vectoring the rescue helicopters, Strohlein was left behind. The next day, the platoon inserted to rescue him found only indications of a firefight.[183] Sergeant Madison Alexander Strohlein became the first HALO operation team member to be listed as Missing in Action (MIA).[184]

Thus, of the three MACV/SOG HALO missions conducted to that point, all experienced limited success. It is not surprising, therefore, that in a subsequent briefing General Creighton Abrams asked the SOG chief when there would be a HALO operation "that accomplishes the mission."[185] The Command and Control Central (CCC) commander, Lieutenant Colonel Galen Radke, who had attended the briefing, sat pondering that very question one night with the CCC recon company commander, Captain Jim Storter, who then insisted on leading the SOG's fourth HALO jump. The next day, however, after learning that the operation had been approved, Storter asked, "What HALO operation?" It

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[183] Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 306.

[184] "POW Network," http://www.pownetwork.org/bios/s/s176.htm (accessed December 11, 2007).

[185] Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 309

turned out that he had drank too much the night before and forgot that he had volunteered.[186]

Storter recruited four[187] experienced non-commissioned officers (NCOs) for the mission and began the training. He appointed Staff Sergeant Miller Moye, an accomplished civilian skydiver, as base man for the operation because of his extensive experience. Unlike the previous HALO teams, Storter and his team used steerable civilian Para-Commander parachutes. In September 1971, the fourth HALO operation was conducted with complete success. It was the first time that a team jumped free fall into enemy territory, at night, landed together without injury, and completed its mission.[188] A month later SOG's fifth and final American HALO jump was conducted. In this case, the insertion was compromised, but all the team members were extracted without casualties.[189]

These first HALO missions illustrate how adopting an innovation early pays off later. The concept of HALO was conceived and its usefulness demonstrated many years before it developed to the point of viability. HALO was conceptualized originally as having increased capability over low-level, static line parachuting. But other than the

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186 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 310.

187 lthough Captain Storter recruited four commandos for the mission, one was injured in training.

188 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 311.

189 Plaster, *SOG: The Secret Wars of America's Commandos in Vietnam*, 312.

Russians, who accepted a manually operated ripcord[190] early on, all other airborne forces continued to use static line systems. When free fall was first contemplated, it seemed impractical because jumpers were not able to maintain stability while free falling. But in the late ‘40s and early ‘50s civilian jumpers[191] learned how to remain stable in freefall and move through the sky to group with other jumpers. Still, even after the military adopted the concept, it took many years before it was used in combat. Since its adoption and use in a combat situation, however, the HALO innovation has continued to develop and become a very usable concept. Although the first missions were flawed by problems, later technology and experience overcame those issues. This is also the case with the other innovations discussed here: some of the concepts need further development before they can be accepted for use. What is clear is that only the experience and technology that come from exploration and development will make them usable.

This thesis recommends therefore that military decision-makers explore and develop the air insertion innovations described here – and then at least consider them for adoption. HALO was not used as a means of clandestine air insertion until many years after it was initially explored. However, it was primarily the pool

[190] Although the Russians adopted a manually operated ripcord they did not necessarily utilize free fall until later.

[191] While the history of jumpers obtaining stability during free fall is vague, many attribute the development of this technique to Leo Valentin.

of experience that resulted from this early exploration that led to its development and present day viability.

The innovations discussed in this thesis have the potential to further expand HALO and HAHO, and their incorporation could have definite advantages. For example, there could be greater HAHO range (HGR parachute), HALO offset operations (with rigid wing and possible future iterations of wing suits), an expanded capacity for what can be inserted with trained operators (tandem), and an ability to jump from fixed objects (BASE). Nevertheless, some of these concepts do have limitations that currently make them marginally useful at best.[192] This is where further exploration and development could prove most valuable. Innovation and technology seldom start with an optimal product. At present, only two of the five innovations - Tandem[193] and HGR parachute[194] - have been adopted for limited use by U.S. SOF, while the rigid wing is being considered. All of the concepts have limitations and bounded applications, but then, so do ships, fighter aircraft, and tanks. All military systems have advantages, disadvantages and limited applications.

As noted in the Introduction, it is the technology that is available that usually drives the use of parachute systems and other technologies in military applications. Many inventive concepts come from the civilian sector. In a capitalist society, this is understandable because the

[192] See the limitations and shortfalls of each section described in Chapter II.

[193] Section E. of Chapter II covers tandem parachuting and discusses the extent to which it has been adopted.

[194] Section C. of Chapter II covers the HGR parachute and discusses the extent to which it has been adopted.

competition that comes from free enterprise encourages innovation. After all, many military innovations, such as small arms[195] and aircraft[196] came from the outside. If a capability has potential, it should be developed fully before disregarding or rejecting it. While organizations such as Defense Advanced Research Projects Agency (DARPA) exist to explore and develop advanced technologies, there doesn't appear to be any competition in this capitalistic enterprise. SOF could explore these innovations and sanction the specialized companies doing the development. It is competition like that among innovating companies that America needs if it is to remain in the forefront of the technology.

B. IMPLEMENTATION

In Admiral William McRaven's book, *Spec Ops: Case Studies in Special Operations Warfare*, he modifies the U.S. Army's principles of war[197] to "more accurately reflect their relationship to a special operation." McRaven calls the resulting concepts "the six principles of special operations" and they include: simplicity, security, repetition, surprise, speed, and purpose. He relates them to eight historical special operations, showing how they allow SOF to gain relative superiority. His model for evaluating each of the special operations has particular value because it shows that if one of the principles was

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[195] Samuel Colt was an industrialist who developed and marketed the hand gun and was not a military man.

[196] Orville and Wilbur Wright were inventors and had no military application in mind when they set out to design their flying machine.

[197] "Joint Publication 3-05: Doctrine for Joint Special Operations," http://www.dtic.mil/doctrine/jel/new_pubs/jp3_05.pdf (accessed November 30, 2007).

"overlooked, disregarded, or bypassed," the result was a failure in the operation.[198] McRaven's principles are also applicable to the consideration of the air insertion innovations discussed in Chapter II.

The model presented here differs from McRaven's in that only the aspects of insertion or extraction are being examined. Nonetheless, addressing how the innovations relate to the six principles provides valuable insight into how and/or why the concepts should be explored, developed, and potentially implemented. The current capability of each, as discussed in Chapter I, provides the baseline for the discussion.

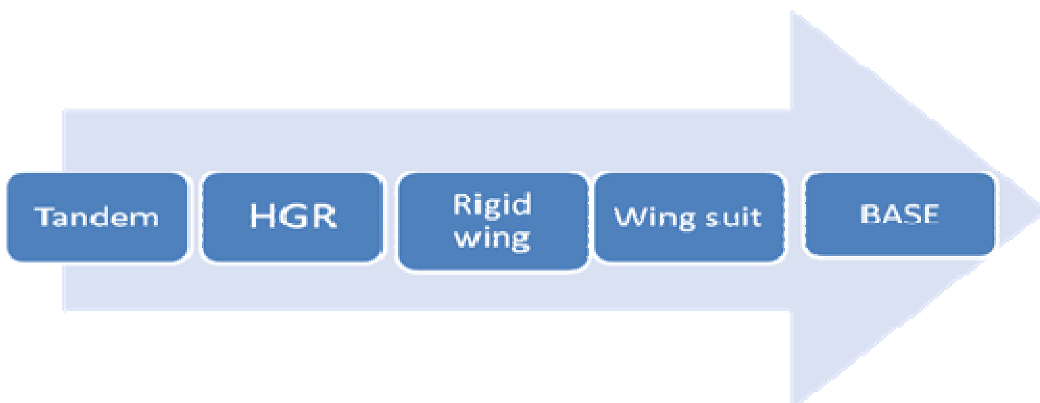

Figure 27. Spectrum of Comparative Simplicity[199]

The first principle, simplicity, is fundamental to determining the successful use of any of the innovations.

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[198] William H. McRaven, *Spec Ops : Case Studies in Special Operations Warfare : Theory and Practice* (Novato, CA: Presidio, 1995), 8.

[199] The innovations to the left are closer to the current capability and as the innovations move to the right they get increasingly more complicated. The methods closer to the left end of spectrum would require less development before adoption.

While none of these methods are “simple,” they all fall within a spectrum of comparative simplicity relative to currently available capabilities. The research that supports this thesis is extensive, but it is by no means exhaustive. Further research and development should be done before any of these methods are adopted. In addition, their application requires timely and accurate intelligence on weather, terrain and threat environment where they are to be employed. These innovations could simplify operations, helping teams “to avoid or eliminate obstacles that would otherwise compromise surprise and/or complicate the rapid execution of the mission.”[200] Each of the methods discussed could play an innovative role in future operations, but to maximize success both their potential and their limits must be fully understood.

McRaven’s second principle is security; its purpose is “to prevent the enemy from gaining an advantage through foreknowledge of the impending attack.”[201] This does not mean, however, that considering the innovations for adoption needs always to be kept a secret. For some of them, like BASE, rigid wing, or wing suit, where an advanced capability may affect tactics, its adoption should not be shared. For capabilities such as tandem or the HGR, however, which effect only minor changes in insertion tactics, hiding their adoption is less important. After all, these concepts were all developed in the civilian sector and information pertaining to them is readily

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[200] McRaven, *Spec Ops: Case Studies in Special Operations Warfare : Theory and Practice*, 13.

[201] Ibid., 14.

available through open sources. Security becomes vital, however, when it involves the approaching employment of a method, because a failed security plan could cause the loss of the element of surprise.

McRaven's third principle, repetition, plays an important role when an innovation is being considered either for adoption or employment. Combat units must practice their skills until they reach the point where they become second nature. Conducting complete, start-to-finish drills for an operation is vital to an operation's success. But team members must also be trained for each individual element of the operation prior to putting them together in a full rehearsal. Thus, if adopted, each of the innovative methods must be practiced to the point that the probability of success is acceptable to the decision-makers. However, it is difficult to determine whether a given innovation's probability of success can attain an acceptable level without its adaptation for military use and further development. For example, most of the rigid wings, all the wing suits, and all BASE gear have been developed for civilian use. Without further development with military use in mind, the likelihood of their successful use is difficult to determine.

According to the U.S. military's *Joint Pub 3-05, Doctrine for Joint Special Operations,* "Surprise" - McRaven's fourth principle - is often the most important in conducting successful special operations and the survivability of employed SOF."[202] Air insertion by

[202] *Joint Publication 3-05: Doctrine for Joint Special Operations*, I-6.

parachute can provide both tactical and operational surprise, allowing SOF to achieve relative superiority. This is another good reason why innovative air insertion techniques should be explored, developed and exploited. Those discussed in Chapter II have potential to enhance surprise, increasing the chances of a successful operation. An offset insertion can catch the enemy off guard and innovations such as the rigid wing and the HGR parachute expand the military’s current capability for offset insertion. Moreover, the five innovations covered in this thesis may not be the only ones with a potential for surprise in future operations. I recommend, therefore, that these ideas, and others not covered, be researched further and implemented if they can enhance the advantage of surprise in future operations.

Although usually associated with surprise, speed, McRaven’s fifth principle, is another aspect that has value when considering innovative air insertion methods. Speed amplifies the element of surprise by allowing the attacker to stay ahead of the enemy after the battle has been joined. With speed, the attacker can be long gone before the enemy can react – and if it does react, it can be engaged before it can organize. All the innovations discussed have the element of speed as an advantage. And combining innovations could further enhance the speed dimension. For example, an offset insertion, using a HGR parachute onto a building or mountain top, could achieve further mobility upon completion of the objective by using BASE-specific gear.

McRaven’s sixth and final principle is purpose, which means that all the people involved understand and are dedicated to the mission. This entails organizing a testing and development unit to further research, not only these concepts but also any other parachuting innovations with military potential. Purposeful SOF teams who train extensively with these techniques are also a necessity, because only operators who know both the limitations and the advantages of these air insertion methods can maximize a mission’s success. Having operators with just enough experience to conduct training exercises is not enough. Future air insertion specialists will need to be far more experienced than currently qualified HALO/HAHO operators.

Discussing these principles provides some insight into the consideration of the above innovations. The principles address both how and why these innovations would be explored, developed, and potentially implemented. Simplicity addresses how; although the systems are rather simple much more work must be done before implementation. Simplicity also allows us to consider why; application of these concepts could be used to simplify a special operation. Security addresses how; contemplation of these systems is not a security issue but acknowledgement of pending employment would be. Repetition addresses how; with repetition the probability of success would be maximized. Surprise allows us to consider why; the element of surprise is vital to the success of a special operation. Speed is a reason why; these innovations have the element of speed as an advantage over other insertion methods. The final principle, purpose, addresses how; special operators who further develop and implement these concepts must be

focused on these new concepts more than the attention they currently place on insertion skills.

C. FINAL THOUGHTS

To some observers, some of these innovations may seem too impractical, dangerous, or futuristic for serious consideration. It is often hard to see the potential of an innovation when viewing it through a lens shaped by currently available technology. For instance, when airplanes were first invented, no one could imagine a jumbo jet that would carry more than 500 passengers much less that even the elderly would dare to fly in them.[203] It was only the invention of jet engines, certain alloy materials, and advanced computer systems that brought such jets into existence – and made it routine for the average person to fly in such a craft. Some suggest that “smart materials”[204] is the technology that will propel current innovations into the future. Imagine a material used in the construction of a wing suit that would allow the wings of the suit to have a greater span and to become rigid when necessary, yet still be flexible enough for deployment and maneuverability. Materials development will affect all of these innovations as they evolve into fully viable concepts, and only time will tell where they will go from here – and what further innovations they will produce. In the meantime, those we have should be adopted and further development encouraged.

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[203] The Airbus A380 came into service in 2007; it carries 525 passengers.

[204] Smart materials are materials that have one or more properties that can be significantly altered in a controlled fashion.

As pointed out in Chapter I, the U.S. airborne program was initiated in response to other countries’ development of this capability. And other nations’ SOF will eventually endorse and profit from their use of the innovations discussed here. Will the United States wait and be the last to adopt them? Let us hope not! After all, as was the case during WWII, many American civilians are already involved in the development of these innovations, even though the military may or may not have adopted them. This involvement of American civilians is an advantage that may have far-reaching results if exploited and put to good use.

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